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PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-NINTH YEAR, 1900–1901.

BOSTON, January 24, 1901.

THE 547th regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, Rogers Building, at 8 P.M., Professor Swain presiding. Forty-five persons were present.

The following were elected to Associate Membership: P. Schuyler Miller, Assistant Chemist, Department of Water Supply, Brooklyn; William C. Ewing, Civil Engineer; Henry R. Batcheller, Mining Engineer. The records of the previous meeting were read and approved.

Mr. William H. Lincoln, President of the Boston Chamber of Commerce, was introduced and gave a most interesting and comprehensive talk on "Shipment of Freights to Europe." The diminution in the rate of freights, and the change in the methods of transportation from sailing vessels to immense freighters, have enabled the United States to compete with the world in commercial enterprises. Last year the balance of trade was over $600,000,000 in our favor, almost wholly with Europe, and chiefly with Great Britain. England purchases over $400,000,000 more in supplies from the United States than we import from her.

Since the invention of the ammonia process of refrigeration, the exportation of fresh meats to England has increased enormously, re-

sulting in the lowering of the price of meat in England to one-half. Likewise the shipment of live stock has increased. The industry was started in 1875 and carried on for several years at a loss. Often the entire cargo would be swept away during a storm, or die of exposure. At present the methods of transportation have become so perfected, that last year the Leyland Line carried 30,000 head of cattle with a loss of only 18.

Of the world's crops, the United States produces: 80 per cent. cotton; 80 per cent. corn; 30 per cent. provisions; 25 per cent. wheat; 80 per cent. iron; 33 per cent. coal; 40 per cent. steel. Our manufactured products exceed those of England, France and Germany combined. Mr. Lincoln's paper is published in the TECHNOLOGY QUARTERLY for March, 1901.

In the discussion which followed, Professor Swain referred to the manufacture of Portland Cement as an illustration of our ability to enter and successfully compete with well-established European industries. The thanks of the Society were extended to Mr. Lincoln for his instructive address.

BOSTON, January 31, 1901.

A special meeting of the SOCIETY OF ARTS was held on this day at the Institute, Rogers Building, Professor Cross presiding. One hundred and seventy-five persons were present. The report of the previous meeting was read and approved.

Professor George E. Hale, Director of the Yerkes Observatory, spoke on "Astronomical Photography with the great Visual Telescope of the Yerkes Observatory." This telescope, which has a 40-inch objective and 64-foot tube, is the largest refracting telescope in the world. Though constructed for visual observation, Professor Hale has succeeded in using it for photographic work, obtaining results due to its tremendous resolving power.

Owing to this power of separation, the hearts of star clusters have been resolved into thousands of stars, and details of the moon obtained, surpassing all previous work with telescopes especially designed for photographic work. Spectroscopic attachments to the telescope have enabled the constitution of stars and their life history to be carefully studied, likewise the velocity of stars in the line of sight, and of gas eruptions on the sun's surface.

The spectroheliograph, devised by Professor Hale, permits the study of the sun's surface with one color of the spectrum to the exclusion of all others, a method which has already led to important results concerning the sun's surface. Indeed, a large field for research was mentioned as open to the astronomer, using large visual telescopes as photographic ones.

It is to be observed, however, that the objectives of visual telescopes are constructed of glass which is transparent to waves capable of stimulating the sensations of light, but not to exceedingly short ones. Consequently such visual telescopes cannot be used in the photographic study of the invisible portions of the spectrum.

The thanks of the Society were most heartily extended to Professor Hale for his able, clear and very instructive lecture.

BOSTON, February 14, 1901.

The 548th regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, Rogers Building, at 8 P.M., Professor Chandler presiding. Two hundred persons were present. After the regular business had been transacted, Mr. Robert S. Peabody, President of the American Institute of Architects, spoke on "The Designing of the Buffalo Exposition."

A most interesting account was given of the method followed by the eight prominent architects who were chosen to design the Exposition grounds and buildings. Each member of the committee was requested to present a sketch which should embody his ideas regarding the most suitable and artistic plan for an Exposition. At the first meeting of the committee, these plans were carefully discussed, the remarks being recorded by stenographers. After the meeting, each member was presented with a copy of these criticisms and suggestions, and requested to present a new scheme at the second meeting. In this way a satisfactory plan for the Exposition was obtained. The same method of frank criticism was followed in the designing of the buildings, over twenty in number. Some of the latter are to form permanent additions to the city of Buffalo, such as the New York State Building, afterwards to become the home of the Buffalo Historical Society and the Art Museum.

The present Exposition will differ from the Chicago Exposition in many ways. The buildings will be constructed with projecting eaves,

with large tiled roofs, and will be decorated in the most intense colors. Sculpture will be used in profusion for decorative purposes. Many views were shown of the original sketches, the buildings which are already near completion, and groups of statuary.

The selection of Buffalo as the seat of the Pan-American Exposition seems to have been an excellent one, owing to its nearness to Niagara Falls, also to the fact that over 40,000,000 people reside within one night's ride of the city.

The thanks of the Society were extended to Mr. Peabody by Professor Chandler.

BOSTON, February 28, 1901.

The 549th regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, at 8 P.M., in Room 22, Walker Building, Professor William H. Niles presiding. Two hundred and sixty persons were present. After the regular business had been transacted, Mr. Gifford Pinchot, Chief of the Division of Forestry, Washington, D. C., was introduced and spoke on "A Forest Policy for the United States."

The speaker introduced the subject by showing a map of the Forest belts which cover about 37 per cent. of the territory of the United States, after which slides were shown and explained illustrating the character of the timber growth of these belts, likewise the effect of forest fires, and the ruinous policy which is being pursued by the miners and farmers in the South and West. In some mining districts wood is used extensively as fuel, owing to the great expense of coal, without any adequate provision being made to replace the same. Moreover, in the South and West large tracts of excellent timber are destroyed to be converted into very poor farming land. The speaker referred to the influence of forests upon climatic conditions, and especially emphasized the dependence of the 200 millions acres of land devoted to agriculture in Oregon for its water supply upon the preservation of the forests in that state.

The latter part of the lecture was devoted to a consideration of the features which must dominate any forest policy adopted by the United States Government. The methods successfully followed in Germany are impracticable in this country, owing to the difference in the customs and habits of the people. With us, moreover, the lumber industry is

an exceedingly important one, the amount of lumber used per head being greater than anywhere else in the world. Consequently any governmental policy must preserve the forests, and at the same time consider these rights and interests. In this country, also, great damage results from forest fires, which are seldom known in Germany. Experience has shown that the following factors should be considered in the framing of any forest policy for the United States:

1. Geography of the timber belt.
2. National habits of mind.
3. Grazing interest.
4. Fires.
5. Large lumber interests.
6. Relation of forests to water supply.
7. The tax rate on timber land. This should never be so high as to prevent the owner from holding the land for timber.
8. A Bureau should be established in Washington to which persons could come or write for advice and information.
9. There should be a body of young men trained in forestry to take charge of a forest policy and put it into successful operation.

At the close of the lecture remarks were made by Mr. Egerton, recent Chief of the Division of Forestry; Mr. Harvey N. Shepard, Chairman of the Board of Trustees of the Appalachian Mountain Club Real Estate; and Professor Fay, of Tufts College.

The thanks of the Society were extended to Mr. Pinchot for his most interesting and instructive lecture.

BOSTON, March 14, 1901.

The 550th regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, at 8 P.M., Mr. George W. Blodgett presiding. Ninety-five persons were present. After the regular business had been transacted, Dr. Henry Fay, Assistant Professor of Metallography at the Institute, was introduced and spoke on "The Use of the Microscope in the Study of the Chemical Constitution and Physical Properties of Metals." The need of some method of investigation for distinguishing between steels of the same composition, but of different physical properties, led to a microscopic study of the structure. The foundations of this microscopic analysis were laid by Sarby, and

extended by Martens, Osmond, Roberts-Austin, Stead, Sauveur and others.

It was found that an exact analogy existed between solutions and alloys — steel itself acting as an alloy. This analogy is most advantageously shown, 1st, by a study of the fusibility curves; 2d, by examination of polished and etched sections with the microscope.

The fusibility curves of alloys have been found to fall under three general classes:

I. Two metals which form solid solutions give a straight-line curve connecting the two melting-points. Examples of this class are the alloys of silver and gold, and bismuth and antimony.

II. Two metals which neither form solid solutions nor compounds, give a two-branch curve, meeting in an eutectic point, which is lower than the melting-point of either metal. Typical examples of this class are the alloys of tin with bismuth, lead, and zinc, and the alloys of zinc with aluminum and cadmium.

III. Two metals which form one or more compounds give a curve, the number of branches of which is $2n + 1$ where n represents the number of compounds. In this class one of the compounds may form a solid solution with one of the pure metals, which would, consequently, modify the character of the curve, and therefore change the number of branches. Examples of this class are the alloys of copper with antimony, tin, and bismuth; those of aluminum and gold, antimony and zinc, and tin and nickel.

The study of the microstructure of these three classes of alloys confirms very decisively the fusibility curves. In the first class it is known that the solvent and dissolved substance separate out together. The microstructure of metals which form solid solutions shows a homogeneous mass in which it is difficult, if not impossible, to distinguish between the two constituents. In the second class, where the freezing-point of the pure metal is considerably lowered by the addition of the other metal, there is first a separation of pure solvent, and as the temperature of the solution is lowered, the pure metal continues to separate until the concentration of the resulting solution has reached that of the eutectic alloy, when the mass solidifies as a whole. The microscopic constituents, consequently, should be pure metal and the eutectic, the amount of each depending upon the proportion of the two constituents. As the eutectic is the alloy in which the two constituents are each saturated with the other and the two separate simultaneously, we

find a structure made up of alternate layers of the two metals. The structure for all eutectics is very characteristic, resembling the fine line markings of the thumb. The eutectic may consist of two metals, a metal and a compound, or two compounds, but in all cases its structure is characteristic. The presence of compounds in the third class is usually recognized by their crystalline form, the forms of some of them being very characteristic, such as is the case for the compound $SnCu_3$. When, however, a compound forms a solid solution, the detection of the two constituents is much more difficult.

The microstructure of alloys was illustrated by photographs of lead-tellurium alloys.

Steel was considered as an alloy of iron and carbide of iron, and was shown to belong to the second class of alloys. The microstructure of steels subjected to various heat treatment was illustrated by photomicrographs.

The thanks of the Society were extended to Dr. Fay for his instructive address.

BOSTON, March 28, 1901.

The 551st regular meeting of the SOCIETY OF ARTS was held on this day at the Institute, at 8 P.M., in Room 22, Walker Building, President Pritchett presiding. Over three hundred and fifty persons were present. The following persons were elected to Associate Membership: Mr. F. F. Low, 101 Milk Street, Boston; Mr. R. G. Hall, Pueblo, Colorado; Professor C. E. Fuller, Massachusetts Institute of Technology; Dr. F. J. Moore, Massachusetts Institute of Technology; Mr. R. R. Laurence, Massachusetts Institute of Technology; Mr. C. W. Berry, Massachusetts Institute of Technology; Mr. C. H. Hapgood, Massachusetts Institute of Technology.

Dr. M. I. Pupin, Professor of Electro-Mechanics at Columbia University, spoke on "Electrical Wave-Transmission." Experiments on the propagation of waves over cords were shown. A résumé of the lecture will be found below, pages 89–91.

The thanks of the Society were most heartily extended to the speaker for his interesting, instructive, and clear presentation of the subject.

GEORGE V. WENDELL, *Secretary.*

TESTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY TAPE APPARATUS.

By ALFRED E. BURTON, S.B., Professor of Topographical Engineering, Massachusetts Institute of Technology,

AND

JOHN F. HAYFORD, C.E., Inspector of Geodetic Work, United States Coast and Geodetic Survey.

Introductory Note.

Alfred E. Burton.

The so-called "Massachusetts Institute of Technology Tape Apparatus," is an indirect product of the Summer Schools of the Civil Engineering Department. As early as 1888, at the Summer School held at South Deerfield, Massachusetts, a base line was measured with the suspended steel tape. During this and the following two years, the apparatus used was similar to that employed by the Missouri River Commission in 1885, slightly modified to increase the speed of measurement. In 1891, Mr. Harry C. Bradley and Mr. George A. Campbell took for their thesis the subject of base measuring with the steel tape. To Mr. Bradley is due the design of an automatic stretching device which makes it easy to secure a uniform tension, the value of which can be determined to a fraction of an ounce. Mr. Campbell designed an apparatus to determine the coefficients of expansion of tapes in air. He also suggested and discussed the method of determining the expansion of the tape by a measurement of its electrical resistance. In 1892, Mr. William C. Thalheimer in his thesis continued the work on the coefficients of expansion of steel and brass tapes begun by Mr. Campbell. In 1892, measurements were made with the steel and brass tapes, using their relative coefficients of expansion, for the determination of the temperatures. That year, several measurements were made at night, and in this work the actual differences between measurements did not exceed one part in

a million. At the Summer School held at Keesville, New York, in 1893, Mr. Campbell took direct charge of the base measurements in order to test, in the field, the method of determining electrically the expansion of the tape due to temperature changes. The degree of precision obtained was highly satisfactory, but the field work was slow, for the Wheatstone Bridge employed was not adapted for rapid work. The necessary modifications could not be attempted at the time, but were later found embodied in a form of Wheatstone Bridge for temperature measurements, invented by two of the Institute graduates.

In 1895 a paper[1] was read before the SOCIETY OF ARTS by Mr. George C. Whipple, graduate of the class of 1889, describing "The Thermophone" recently invented by Henry E. Warren, '94, and himself. At this time it occurred to the writer that here was an instrument for solving in the simplest manner the long-vexed problem of the determination of the temperature of a steel tape when used in base measuring. The thermophone, with slight modifications, could be made to do the work expeditiously and satisfactorily. Messrs. Warren and Whipple entered into the scheme gladly, and both lent their aid towards the final solution. Mr. Warren in the Summer School of 1896, held at Machias, Maine, took direct charge of the base measurements and obtained results that surpassed the most sanguine expectations. Meanwhile, in 1895, Messrs. Francis E. Matthes and Gerard H. Matthes had taken up steel tape measurements as a thesis, and they undertook and carried through in a most satisfactory manner the calibration of a thermophone for the 100-meter steel tape, and the 100-meter German silver wire. The thermophone, as completed by these students, reads directly the mean temperature of the tape to a tenth of a degree Fahrenheit.

The above account gives a brief history of this tape apparatus up to the time the test was made by the United States Coast and Geodetic Survey, in November, 1900. In this test many of the minor appliances that had been used to further increase the accuracy of measurements were left out, the officers of the Coast Survey considering that we were needlessly increasing the refinement of measurement and thus decreasing the speed of work. The measurements at the Summer School have always shown a smaller probable error than was brought out by the test.

[1] See *Technology Quarterly*, July, 1895.

It appears to the writer that in this evolution of a base measuring apparatus there is an interesting example of thesis work which has tended to develop the faculty for original research.

A number of students' names have been mentioned as directly concerned in the development of this apparatus, but it would only be fair to say that valuable suggestions have been from time to time received from other students, and from several of the instructors at the Summer Schools.

Tests of the Massachusetts Institute of Technology Tape Apparatus, Made by The Coast and Geodetic Survey in November and December, 1900.

John F. Hayford.

The object of these tests of the Massachusetts Institute of Technology tape apparatus was to determine its adaptability to the measurement of primary bases by the Coast and Geodetic Survey. In considering these tests it should be kept clearly in mind that results of the extremely high degree of accuracy which are stated to have been obtained with this apparatus are unnecessary in connection with primary triangulation. The base measurement is ordinarily the strongest part of the work, and very little accuracy is gained by reducing the probable error of a base further after a probable error of one part in 500,000 has been obtained. In making the tests it was continually kept in mind that what was wanted was a method of measurement which should be as rapid as possible while securing a probable error not exceeding one part in 500,000.

Two full days were devoted to the tests in November at Washington, and three afternoons on the Alice Base Line in southern Texas in December.

The tests made at Washington consisted of repeated readings on a single tape length between fixed points, the tape being supported at intervals of 25 meters on nails or a wooden arm. One end of the tape was fixed rigidly, and the readings taken at the other end. No glass rollers were used to relieve the friction at the reading end. The conditions differed from those ordinarily encountered in the measurements by students at the Massachusetts Institute of Technology, in that the support interval was changed from 10 to 25 meters; that there was considerably more friction at the fixed nails or other

supports than with the swinging hook supports ordinarily used; and that a little extra friction was encountered at the reading end. The conditions as stated were similar to those which are allowed to exist with the 50- and 100-meter tapes actually in use during this season in the Coast and Geodetic Survey base measurement, and it was believed that the desired accuracy, namely, a probable error of one part in a half million, could be obtained under these conditions. On November 13, ninety readings of a single tape length were taken between 10.24 A.M. and 8.54 P.M., and on November 19, seventy readings between 10.10 A.M. and 7.51 P.M., by Mr. L. A. Fischer, Adjuster, United States Office of Standard Weights and Measures, and the writer. On each day the temperature conditions varied greatly, part of the measurements being made in bright sunlight, a part with one portion of the tape in sunlight and another in shade, other measurements being made during daylight but with the sun under a cloud, and the latest measurements on each day being considerably after sunset. The measurements all being reduced to a fixed temperature, using the known coefficient of expansion of the tape, showed a total range of 2.3 millimeters on the first day, and 2.6 millimeters on the second. On taking the sums of the measurements in successive groups of ten, corresponding to measurements of 1 kilometer each, the total range was 8 millimeters on the first day, and 7 millimeters on the second. These ranges are no greater than are obtained in the regular base work of the Survey which serves to give a probable error of one part in a million or less on each base, and therefore indicate that even under these conditions the tape gave sufficiently accurate results for the required purpose.

On December 10, on the Alice Base Line, Professor A. E. Burton and the writer spent the afternoon in making measurements of a single tape length, the tape being supported upon tripods. This afternoon's work was of little value except as preparation for the later tests. Similarly, on December 13, 1 kilometer of the base was measured once with the aid of the base party under Mr. A. L. Baldwin, and served mainly to give the party practice with the apparatus. On December 17 a section of the base nominally $\frac{1}{2}$ kilometer long was measured six times with the aid of the base party, two or more readings of the tape and thermophone being taken in each position. During these measurements instrument tripods, modified slightly to adapt them to the purpose, were used as marking points for the ends

of the tape, and the middle point of the tape was supported on one of the tripods ordinarily used with the base bars. The tape, therefore, hung in two catenaries, each 50 meters long. At the middle support the tape rested across a heavy metallic roller which ordinarily supports one end of a base bar. This roller served to relieve the friction to a small extent, but was, doubtless, less effective for that purpose than the swinging hook. The tension was applied with the Massachusetts Institute of Technology tension apparatus, and was 7.38 kilograms. The results of the measurements cannot be given in absolute units as, at the date of writing, the length of this section of the base has not yet been computed by the base party. The residuals from the mean of the six measures were, however, + 2.40 millimeters, — 3.12 millimeters, — .82 millimeter, + .37 millimeter, — .64 millimeter, + 1.84 millimeters.

During the first two measurements no friction rollers were used at the reading end of the tape. During the remaining four measurements a small roller was used for that purpose, and the residuals show clearly the increased accuracy gained thereby.

A study of the results, and especially of the readings taken in quick succession with the tape in a given position, indicates that while with the 50-meter interval between supports the required degree of accuracy could probably be obtained during perfectly still weather, the effect of the wind upon the apparent length of the tape is so great that under ordinary conditions this interval is too great for safety. The total time required to make these six measurements of the half-kilometer section was 250 minutes, or 83 minutes per kilometer, in spite of various delays due in part to inexperience with this apparatus, and in part to defects in the apparatus itself which may easily be remedied.

A mere statement of the numerical results of the tests as given above indicates but poorly the information furnished by them. During the tests as careful studies as possible were made of the detail of the method and the apparatus. The results of these studies can be most conveniently stated in a readable form as an opinion upon the apparatus as a whole.

The three principal advantages of the thermophone method of determining the temperature of the tape are:

1. That the thermophone gives a determination of the actual temperature of the tape, regardless of whether the heat reaches the tape

in the radiant form or otherwise; whereas the ordinary mercurial thermometer receives at its bulb less radiant heat than a steel tape exposed under the same conditions, and, therefore, indicates too low a temperature when used in daylight. Attempts to get rid of this error by blackening the bulb of the thermometer or sheathing it with metal have proved unsuccessful, and it has, therefore, been absolutely necessary up to the present time to use steel tapes at night only when results of a sufficient degree of accuracy for geodetic purposes were required.

2. The thermophone furnishes an instantaneous determination of the temperature of the tape, whereas the mercurial thermometer responds much more slowly to changes of temperature than the tape, and therefore gives indications which are considerably in error at any instant whenever rapid and irregular fluctuations of temperature are in progress.

3. The thermophone furnishes a measurement of the actual mean temperature of the whole length of the tape, whereas with mercurial thermometers all that can be hoped for under the best possible conditions is a determination of the tape temperature at two, three, or more points at which thermometers are placed.

In regard to the Massachusetts Institute of Technology Tape Apparatus as a whole, the writer is convinced:

1. That with the thermophone apparatus in its present form, and using all refinements, measurements can be made, even in daylight and when the temperatures are varying rapidly, with a much higher degree of accuracy than is possible with tapes and mercurial thermometers even under good conditions at night.

2. That after the apparatus has been modified and strengthened at certain points with reference to making it proof against comparatively rough usage and capable of quicker manipulation, certain refinements being omitted, much more rapid measurements can be made with it than with any form of bars, and probably more rapid than with the present form of tape apparatus, if the tripod method rather than the stake method is used.

3. That it can be used efficiently with no more previous preparation of the ground than is necessary for bar measurement by substituting tripods for the marking stakes at the tape ends and for the intermediate supports.

Base measurements with bars have ordinarily been made with the

bars supported upon portable tripods. It has not been feasible to measure primary bases with tapes similarly supported upon tripods, since it was absolutely necessary to make the measurements at night to secure the necessary degree of accuracy with the means heretofore available for determining the temperature. The thermophone apparatus determines the temperature with all necessary accuracy in daylight. Hence, it is now possible to substitute tripods, or other portable supports, which may be placed in position as the measurement progresses, for the fixed stakes which have heretofore been used. With a well organized base party familiar with the work, the setting of the stakes requires considerably more time than the subsequent double tape measurement of the base. For example, the base party which has just finished its operations, found it possible to make two measurements of each kilometer of the base in from 1 to $1\frac{2}{10}$ hours upon an average, whereas the setting of the stakes on a single kilometer required $2\frac{1}{2}$ to 3 hours, six or eight men being required for the tape measurement, and four for the stake setting. If the Massachusetts Institute of Technology Tape Apparatus is used upon stakes, no time can be saved in the measurement, and the only thing that will be gained by substituting it for the tape apparatus at present in use in the Survey, using mercurial thermometers, is that the measurements may be made in daylight, instead of at night. If tripods are substituted for stakes, however, the only previous preparation of the ground other than clearing it, is a very rough preliminary measurement made with a tape dragged upon the ground, requiring, say, 45 minutes per kilometer for a party of three men; and this rough measurement is necessary even when bars are used. It is to the Massachusetts Institute of Technology Tape Apparatus used upon tripods or other temporary supports, rather than upon stakes, that one must look for gain in time over the tape methods now in use in this Survey.

In closing, it may be noted that the attempt to substitute a 50-meter support interval for the 25-meter interval now in use was made because such a change, if feasible, would be conducive to very rapid work with a tripod method, the number of necessary supports being greatly reduced.

ELECTRICAL WAVE-TRANSMISSION.

By MICHAEL I. PUPIN, Ph.D.

Read March 28, 1901.

Electrical wave-transmission over a wire conductor has a mechanical analogy in wave-transmission over flexible cords. The application of a force to one end of a cord develops three reactions: mass, tensional, and frictional reactions. The energy used up in overcoming the first two is non-dissipative, *i.e.*, it is stored up in the cord along which it is propagated; whereas, the energy consumed against frictional reaction is wasted as heat. Consequently, if there be sufficient frictional resistance, the wave will not extend far from the point at which the impressed force is applied before the energy imparted to the cord (as kinetic and tensional energy) becomes dissipated as heat. In the case of wave-transmission along a cord, it is this dissipative factor which causes the wave attenuation.

Similarly, when an alternating electromotive force acts on an electric circuit, the energy imparted to the wire conductor encounters three reactions: *inductance* reaction, which is the same in form as the kinetic reaction of a vibrating cord and is non-dissipative, its work being stored up in the system as magnetic energy; *capacity* reaction, the law of action of which is identical with the law governing the tensional reaction in strings, likewise non-dissipative; *resistance* reaction, in the overcoming of which heat is generated, therefore it is dissipative. Consequently in electrical wave-transmission, the energy is continually dissipated as heat on account of the resistance reaction and causes the attenuation which limits telephony over long conductors, particularly over cables.

Evidently, to diminish the attenuation in either of the above cases the non-dissipative factor must be made larger in comparison with the dissipative or frictional reaction, since a relatively smaller dissipation of energy would result. The conclusion is that the transmission over cords must be better through a dense medium, or cord, since the mass-reaction is thereby increased.

To illustrate this point, a light cord lying on an inclined rough surface may be set into periodic vibration at one end by a suitable mechanism. Owing to friction, the wave energy on the cord is propagated only a short distance, the attenuation being very marked. On increasing the tension and thereby increasing the tensional reaction, the wave progresses much further. By substituting a cord of larger mass, the distance of the wave propagation may be noticeably increased. With a given cord, if the tension has been increased as far as possible, what may be done to diminish the attenuation? Assuming that a heavier cord cannot be substituted, the effect of a cord of large mass may be secured by loading the cord with sinkers of metal at periodically recurring points. Certain experiments demonstrate clearly and beautifully, that the transmission can be much improved in this manner, provided the sinkers are suitably arranged.

The following conclusions were drawn from the above experiments: (1) It is more efficient to transmit energy over a heavy than a light cord. (2) A cord, if periodically loaded, may be made equivalent within any degree of approximation, to a heavier uniform cord. It is to be observed that the distance between consecutive loads must be smaller than the length of the wave which is transmitted.

Similar experiments suggested to the author, in the earlier stages of the research, the manner of attacking the electric problem. In any circuit the magnetic inductance (a source of non-dissipative reaction) is limited. It is well known that coils of wire possess large inductance, consequently such coils should act for an electric circuit in the same way that sinkers do for a cord, and the problem of electrical wave-transmission should reduce itself to the placing of inductance coils at proper periodically recurring points on the wire.

In order that such a non-uniform, or loaded, conductor may act as a uniform conductor of large inductance, it is necessary from mathematical analysis to distribute the loads at periodic distances which are small in comparison with the length of wave which is being propagated.

Since electrical waves in telephony are many miles long, it was impossible to carry out investigations on an actual line. An artificial cable, equivalent to 250 miles of line, was arranged in the laboratory at Columbia University, and inductances were placed at periodically recurring points. The current was measured and the waves plotted for the 250 miles. Using several frequencies the results of measurements were compared with the mathematical theory, and were in splendid agreement.

The practical value of this discovery is: (1) That wave-energy for telephony and telegraphy may be transferred over much greater distance. (2) If the distance remain constant, it enables wires of smaller size to be used, thus decreasing the cost of installation. (3) With the same weight of wire as in use at present, the distance of transmission may be greatly increased.

In the Atlantic cable, owing to the small magnetic reaction, and also small capacity reaction, the resistance reaction predominates by far, and the dissipation of energy is therefore enormous. By a proper distribution of inductance coils at periodically recurring points, say $\frac{1}{8}$ of a mile apart, the inductance reaction can be made very much larger than the resistance reaction for all frequencies which are of importance in telephony, and thus the dissipation diminished to any desired limit. The discovery may, and it is confidently expected that it will, result in the telephonic transmission across the Atlantic.

CONTRIBUTIONS FROM THE LABORATORY OF SANITARY CHEMISTRY.

II.

AIR TESTING FOR ENGINEERS.

BY A. G. WOODMAN AND ELLEN H. RICHARDS.

THE increased amount of carbon dioxide above the normal is usually relied upon as an indication of the extent of vitiation of atmospheric air. Hence sanitary engineers, architects, and building inspectors who have occasion to test the efficiency of ventilating systems for private and public buildings, schoolhouses, and halls, are often required to make numerous approximately quantitative determinations of atmospheric carbon dioxide.

For this purpose the usual laboratory methods for the exact estimation of carbon dioxide in the air are not suited. Such methods require the passage of a considerable volume of air for a long time through the absorbing solution, or else the collection of definite volumes of air for subsequent examination, and the use of carefully standardized solutions which must be preserved out of contact with the air and must be accurately measured. The analytical process demands a high degree of skill on the part of the operator, the value of the results obtained being in direct ratio to the care exercised in the collection and examination of the samples. For a comparatively small number of tests made in or near the laboratory where the highest degree of accuracy is desired, these methods are of great value, but for the demands of engineering practice, where in the course of a few hours from fifty to one hundred tests are to be made, and where comparative results rather than great accuracy are required, some simpler form of apparatus is desirable.

Such an apparatus, to be satisfactory, should meet, so far as possible, the following requirements:

(1) It should be sufficiently compact and portable to be carried in the hand from place to place, and should contain within itself everything required for the complete determination of the carbon dioxide.

(2) It should be as simple in construction as possible, and its use should not involve delicate measurements; if automatic in its action, so much the better.

(3) If possible, the apparatus should be made entirely of glass, avoiding prolonged contact of corks or of rubber connectors with any dilute solution which may be used.

(4) It should be so constructed as to protect the solution at all times from the carbon dioxide of the air, especially while the determination is being made, because of necessity such an apparatus must be used within the area of contamination.

(5) The complete apparatus should be sufficient for fifty or more determinations.

(6) It must be capable of giving results of a reasonable degree of accuracy, say within 0.5 part of carbon dioxide in 10,000 parts of air, in the hands of persons having little or no chemical knowledge and minimum skill in manipulation.

(7) If a solution be used in the apparatus it should be one which can be prepared easily from chemicals readily obtained; the solution must maintain its efficiency for a reasonable length of time, if protected from external influences; and the solution should be one which it is not at all dangerous or obnoxious to use.

Experience with several forms of simple apparatus which have been proposed has shown that none of them answers perfectly to the above requirements. Methods which were satisfactory a few years ago are no longer reliable. The question at present is not whether the air contains 15 or 20 parts of carbon dioxide per 10,000, but whether it contains 5 or 8.

Simplicity of apparatus is much to be desired, but it should not be gained at too great sacrifice of accuracy. Even when no greater precision is required than is necessary to meet the demands of practical work, it is out of the question to measure the test solution by means of an ordinary pipette or to preserve it for any length of time in stoppered vials; the strength of the solution is almost certain to be reduced by contamination with the breath, by contact with rubber or cork. In the directions given for the use of these simple forms of apparatus, not enough stress is laid upon the necessity for extreme care in the use of these very dilute solutions, the strict observance of conditions which might well be neglected in ordinary analytical procedures being here an essential factor of success.

Of the various simple methods which have been tried in this laboratory, perhaps the most generally satisfactory from the standpoint of the engineer is that proposed by Dr. G. W. Fitz, and next, the method of Cohen and Appleyard.[1] A brief description of these two methods in their original form may not be out of place here.

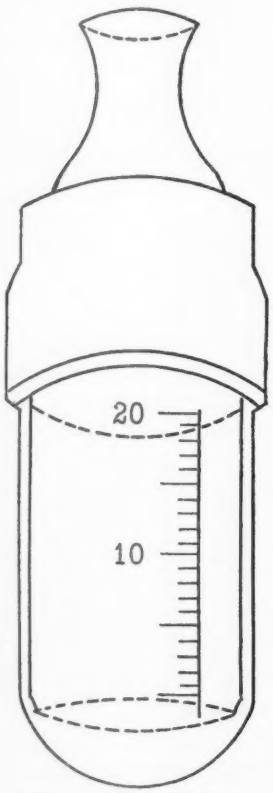

FIG. 1.—FITZ SHAKER. FULL SIZE.

The Fitz method is carried out by shaking a small quantity of dilute lime water, colored pink by phenolphthalein, with successive portions of air until the solution is decolorized. The greater the amount of carbon dioxide in the air, the less will be the volume of air required to neutralize the lime water, and *vice versa*. That is, the amount of lime water remaining constant, the amount of carbon dioxide will vary in a certain inverse ratio to the volume of air.

The solutions used are a 1 per cent. solution of phenolphthalein in alcohol, diluted with 4 parts of water, and a "saturated" solution of lime, made by shaking an excess of unslaked lime with water. The essential parts of the apparatus are several small homeopathic vials, holding about 10 cubic centimeters each, and a "shaker." This consists of a tube of about 30 cubic centimeters capacity, closed at one end, and graduated for a distance of 20 cubic centimeters from the closed end. In this tube by means of a rubber collar, slides a smaller tube which is contracted at the outer end so as to be more readily closed by the finger. The apparatus is shown full size in Figure 1.

Before making a test of the air, 10 cubic centimeters of dilute lime water, prepared by diluting the "saturated lime water" to one one-hundredth of its strength, is placed in each of the vials. When

[1] Chem. News, 70, (1894), 111.

ready to make the test this solution is poured from the vial into the shaker and shaken with successive portions of air until the color disappears. The first test will give the approximate amount of carbon dioxide, and succeeding tests, made by using the solutions in the other vials will aid in approaching the correct result. After thus determining the amount of air required to produce decolorization, reference is made to the table furnished with the apparatus, a copy of which is subjoined.

TABLE USED WITH THE FITZ APPARATUS.

Air in c.c. used.	CO_2 in 10,000.	Air in c.c. used.	CO_2 in 10,000.
30	28	91	9 Bad.
36	22	103	8
46	18	117	7 Fair.
58	14 Very Bad.	138	6
69	12	165	5 Good.
82	10	207	4

This apparatus is certainly sufficiently simple and portable, but a thorough trial of it has shown that it is open to several serious sources of error. One of these is in the preparation of the test solution. One cubic centimeter of "saturated lime water" is a rather small quantity to be measured accurately by unskilled persons, and there can hardly be any question concerning the danger of reducing the strength of the solution through repeated transfers of 10 cubic centimeters of it to the vials by means of an ordinary pipette. Further, the dilute solution must remain in contact with the rubber stopper of the vial until it is used, and while this may not be detrimental in all instances, cases are not infrequent in which the strength of the solution is so greatly diminished that the pink color nearly disappears in a day. In regard to the manner of using the shaker, the directions are decidedly vague upon a most important point. It is stated that the instrument is to be "shaken vigorously twenty-five or more times." A trial of the instrument in outdoor air will readily show that it makes considerable difference whether the apparatus be shaken twenty-five or *more* times. When testing air which is low in carbon dioxide, if the instrument be shaken only twenty-five times, the results will be much below the

actual amount. By shaking it a greater number of times, seventy-five or a hundred, it is possible to obtain results more nearly correct, but this procedure implies a previous knowledge of the condition of the air which is being tested, besides requiring the test to extend over a considerably longer time.

Another objectionable feature of the method lies in the table which gives the relation of the amount of carbon dioxide to the number of cubic centimeters of air used. It is not stated just how this table was constructed, but from the constant relation of the values it is evidently based on theoretical values of carbon dioxide corresponding to a definite strength of lime water. The value of such a table must necessarily depend on the degree of correspondence between the values actually obtained by the use of the apparatus and the theoretical values. It will be shown later that in this particular case the correspondence is not a very close one in all parts of the table.

The second method, that of Cohen and Appleyard, "depends upon the fact that if dilute lime water, colored with phenolphthalein, containing insufficient lime to combine with the carbon dioxide present, is shaken with the sample of air, the rate of absorption of the gas will vary with its volume. The time required to decolorize the indicator will therefore give the quantity of dioxide present. The following apparatus and chemicals are required:

"1st. A clear glass-stoppered bottle of 22 oz. capacity.

"2d. A solution of phenolphthalein prepared by dissolving 0.2 grm. in 100 c.c. of equal volumes of alcohol and water.

"3d. A standard lime solution prepared by diluting 10 c.c. of saturated lime water to one litre.

"4th. Hand bellows for aspirating the sample of air.

"The process is conducted as follows:

"The bottle is rinsed out with water and drained for a minute, and the sample of air is then aspirated by means of the bellows. One-third c.c. of indicator solution and 10 c.c. of dilute lime water are added, and the bottle stoppered and well shaken with both hands until the pink color vanishes. The time required will indicate the condition of the atmosphere."

A table is given in which the method has been compared with Pettenkofer's method. The method is scientific in principle because it recognizes the fact that the absorption of carbon dioxide by lime water is a *time* reaction. The necessary apparatus occupies somewhat

more space than in the Fitz method, but it possesses the special advantage over the latter of showing the condition of the air at a definite moment.

The present work has been carried out in order to adapt these methods more particularly to the needs of the engineer; to eliminate if possible some of the objections to the Fitz method; to adapt the Cohen method to the use of liter bottles, which are more readily obtained and materially shorten the time of shaking; and to make the two methods interchangeable for the same solution. A special form of apparatus has been devised which seems to offer certain distinct advantages. The best methods of procedure have been determined by careful experiment over a wide range of conditions, and the exact interpretation to be placed upon the results has been ascertained by direct comparison with the more exact Pettenkofer method.

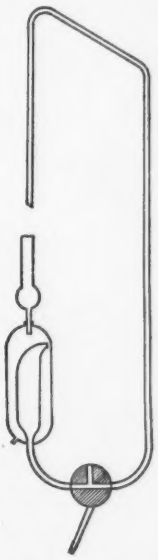

FIG. 2. — AUTOMATIC PIPETTE.

The essential feature of this special apparatus which has been devised consists of an automatic pipette for measuring the test solution. This is a modified form of the pipette first proposed by G. P. Vanier and in use in this laboratory for a number of years. A general idea of it may be had from Figure 2. The manner of using it is extremely simple. The test solution is preserved in a 1-liter bottle of hard glass provided with a doubly perforated rubber stopper. Through one opening passes the siphon tube of the pipette, which is sufficiently long to reach to the bottom of the bottle; through the other passes a glass tube ending just below the stopper and connected with a small bottle containing fresh soda-lime. By means of the three-way cock the solution is allowed to flow into the small inside pipette until it overflows. The stopcock is then turned and the solution allowed to flow out at the lowest point. The pipette is made of such a size as to deliver exactly 10 cubic centimeters. The entrance of atmospheric carbon dioxide as the solution flows out is prevented by the small tube containing soda-lime. The excess of liquid which accumulates in the overflow reservoir may be drawn off when desired. The bottle and pipette are contained in a wooden case about 20 x 8 x 7 inches, outside dimensions, and with the

solution weigh about 8 pounds. The case is furnished with a handle at the top so that it may be carried readily in the hand from place to place. The complete apparatus is shown in Figure 3. The bottle is fastened to the case, and the lower end of the pipette is clamped to a wooden support to keep it from swinging.

The bottle should be thoroughly cleaned and washed with potassium

FIG. 3. — THE COMPLETE APPARATUS.

bichromate and sulphuric acid, and it is best also to steam it for half an hour or so. As a further measure of precaution, the rubber stopper is boiled with dilute caustic potash and thoroughly washed, although the solution can come in contact with it only through splashing while the case is being carried.

The advantages of this arrangement will be obvious. The apparatus, while sufficiently light to be portable, contains sufficient solution for 90 to 100 tests. There is no danger of its being broken with

ordinary care in using it, and it is practically automatic in its action. The solution is protected perfectly from the carbon dioxide of the air and never comes in contact with anything but glass.

The method of preparation of the solutions and the manner of making the tests which have been found to give the best results will be described in detail, since experience has shown that these directions cannot be too minute.

Preparation of the Test Solution. — The solution used is a dilute solution of lime water colored with phenolphthalein. To freshly slaked lime add twenty times its weight of water in a bottle of such size that it is not more than two-thirds full. Shake the mixture continuously for 20 minutes, and then allow it to settle over night or until perfectly clear. The resulting solution is the stock lime solution, or "saturated lime water." If made in the manner indicated, each cubic centimeter of it ought to be very nearly equivalent to 1 milligram of carbon dioxide. If, however, it is desired to know the strength of it more exactly, it may be determined by standard acid.

To prepare the "test solution," pour into the 1-liter bottle of the testing apparatus 1 measured liter of distilled water, and add 5 c.c. of solution of phenolphthalein (made by dissolving 0.7 gram of phenolphthalein in 50 c.c. of alcohol and adding an equal volume of water). Stand the bottle on a sheet of white paper and add the "saturated lime water," drop by drop from a pipette, shaking the bottle thoroughly after each addition, until a faint pink color is produced which is permanent for 1 minute. Now add 12.6 c.c. of the "saturated lime water," shake, and immediately connect the bottle again to the apparatus.

To shorten the time required in testing air which is low in carbon dioxide, it may be found advantageous to use a solution only half as strong as the above. This "half solution" is prepared in precisely the same way, using 2.5 c.c. of the phenolphthalein solution, and 6.3 c.c. of the "saturated lime water."

While this procedure does not give an exact volume of solution, it is believed to be the best for the preparation of this dilute test solution, since it obviates the necessity for pouring the prepared solution from the measuring flask into the bottle in which it is kept; 12.6 c.c. of the stock lime solution is added rather than 10 c.c., in order to keep the values obtained with the resulting solution more nearly comparable with the older values calculated on the supposition that 10 c.c. of "saturated lime water" was equivalent to 12.6 milligrams of carbon dioxide.

TABLE A.

Standard Test Solution. CO_2 in 10,000.	Cubic Cent. Air.	"Half Solution." CO_2 in 10,000.
22.2	50	15.6
18.0	70	12.4
15.1	90	10.2
13.0	110	8.7
11.3	130	7.5
9.9	150	6.6
8.8	170	5.8
8.0	190	5.2
7.3	210	4.8
6.8	230	4.5
6.3	250	4.3
5.9	270	4.1
5.6	290	3.95
5.4	310	3.8
5.1	330	3.7
4.8	350	3.6
4.7	370	...
4.5	390	...
4.4	410	...
4.2	450	...
4.0	490	...
3.9	530	...

Method of Making the Test. — See that the inner tube of the shaker slides readily in the outer one, moistening the rubber collar slightly if necessary. Have the inner tube pressed down to the bottom of the larger one, and measure into the apparatus 10 cubic centimeters of the test solution from the automatic pipette. Pull the inner tube up to the 5 c.c. mark (the bottom of the inner tube serving as the index) and close the end of the tube with the finger. Hold the apparatus horizontally, and shake it vigorously for exactly 30 seconds.

The amount of air which is thus brought in contact with the solu-

tion is equivalent to 30 cubic centimeters, as there are 25 cubic centimeters of air above the liquid when the small tube is forced to the bottom of the larger. Remove the finger, press down the small tube again to the bottom of the larger and draw it up to the 20 c.c. mark. Shake the apparatus again for 30 seconds. The amount of air brought in contact with the solution is now $30 + 20 = 50$ c.c. Repeat the shaking, using 20 c.c. of fresh air each time, until the pink color is discharged. The amount of carbon dioxide corresponding to the number of cubic centimeters of air used will be found in Table A.

Notes and Precautions. — Care should be taken that the finger used to close the end of the tube is perfectly clean, since on a warm day the free acid in the perspiration might easily vitiate the results.

If greater accuracy is desired, the shaker should be filled with the air to be tested before running in the test solution. This may be done readily by filling the shaker with water and emptying it or by forcing air into the tube by means of a small rubber bulb.

The apparatus should be shaken vigorously and continuously during the 30 seconds in order to absorb practically all of the carbon dioxide in 20 c.c. of air. The number of shakings ought not to be less than 100 during this time.

Care should be taken not to contaminate the air while the sample is being taken. The breath should be held momentarily while the air in the apparatus is being replaced, and the sample should be collected as far to one side of the body as possible. It ought not to require over 10 seconds to replace the air, and the entire test, with air containing, say, 8 parts of carbon dioxide per 10,000, should not require over 6 minutes.

If less than 90 c.c. of air is required to discharge the pink color, the test should be repeated, using 10 c.c. of air each time after the first 30 c.c.

It is not necessary to rinse out the shaker after making each test, but it should be carefully washed and dried after using, and the parts kept separate when not in use.

The "half solution" is used in exactly the same manner and amount as the regular test solution, reference being made to the appropriate portion of the table.

For the Cohen method the same solutions may be used and measured from the same apparatus. The samples are collected in white, glass-stoppered bottles of 1-liter capacity. This may be done by aspirating the air with a bellows as directed in the original method, or the bottles may be completely filled with water which is then emptied at the place where the air is to be tested. Ten cubic centimeters of the

test solution are run in from the automatic pipette, the time noted, and the bottle shaken continuously and vigorously with both hands until the pink color vanishes. It will aid materially in determining the exact point of disappearance of the color if a piece of white paper, about $1\frac{1}{2}$ inches by 3 inches, is pasted on the side of the bottle near its lower edge, a similar piece joining it on the bottom of the bottle. In observing the color the solution is held in the angle formed by the pieces of paper and the disappearance of the color is more readily apparent. From the time required the amount of carbon dioxide in the air may be found by referring to Table B.

TABLE B.

CO_2 in 10,000. Standard Solution.	Time. Minutes and Seconds.	CO_2 in 10,000. "Half Solution."	CO_2 in 10,000. Standard Solution.	Time. Minutes and Seconds.
....	0.15	....	4.0	5.45
....	0.30	15.6	...	6.00
....	0.45	12.1	3.9	6.15
16.0	1.00	9.9	...	6.30
13.1	1.15	8.4	3.8	6.45
11.4	1.30	7.2	...	7.00
10.1	1.45	6.3	...	7.15
9.1	2.00	5.5	3.7	7.30
8.3	2.15	4.9	...	....
7.6	2.30	4.4	...	....
7.0	2.45	4.0	...	....
6.5	3.00	3.8	...	....
6.1	3.15	3.7	...	....
5.7	3.30	3.6	...	....
5.4	3.45	....	...	....
5.1	4.00	....	...	....
4.9	4.15	....	...	....
4.7	4.30	....	...	....
4.5	4.45	....	...	....
4.3	5.00	....	...	....
4.2	5.15	....	...	....
4.1	5.30	....	...	....

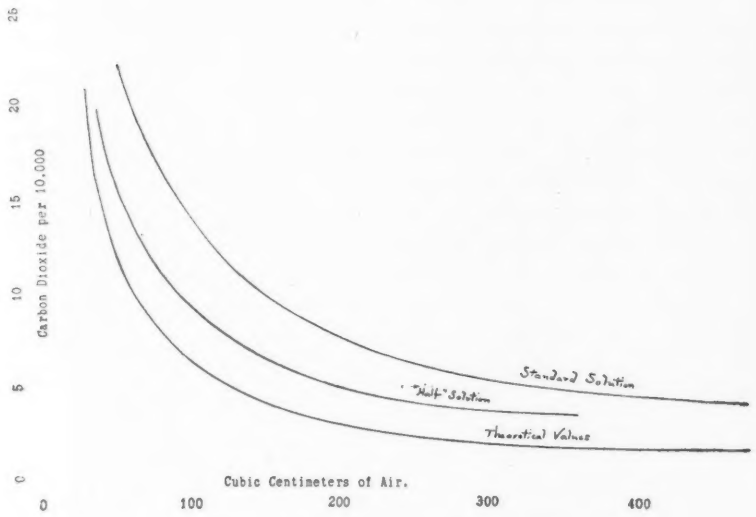

FIG. 4. — CURVES OF VALUES OBTAINED WITH FITZ SHAKER.

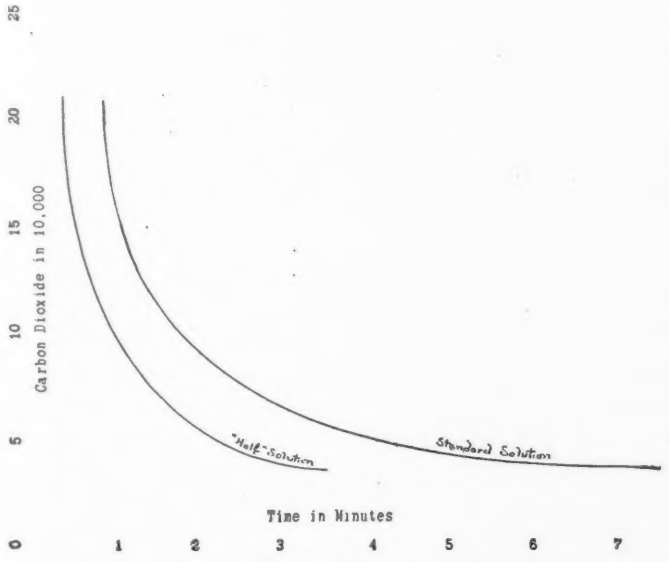

FIG. 5. — CURVES OF VALUES OBTAINED BY COHEN METHOD.

Having found by experiment the best mode of procedure in each case, a number of determinations have been carried out by both methods, using both the standard and "half solutions," in order to determine the correct values to be assigned in Tables A and B. Tests have been made exactly as just prescribed, in air containing varying amounts of carbon dioxide, the results being compared with samples taken at the same time, in which the exact amount of carbon dioxide was determined by the Pettenkofer method. The greater part of the tests were made in duplicate, and by two independent observers in order to eliminate the personal equation. Over 150 determinations were made by the Pettenkofer method, and many more by the others, the average results of a number of tests being taken as a basis for calculation. The samples below 10–12 parts of carbon dioxide were taken directly in rooms under normal conditions. For the samples showing more than this use was made of an air-tight chamber constructed for another purpose, in which the test could be carried out and samples taken for the Pettenkofer method simultaneously. When the air contained more than 15 parts of carbon dioxide, the test was made by using 10 c.c. of air each time instead of 20, as suggested above.

From the comparison of the results obtained, the curves have been plotted which are shown in Figures 4 and 5, each point plotted being the mean of a number of determinations. The values given in Tables A and B have been obtained by interpolation in these curves. It will be observed in Figure 4 that the values obtained by actual experiment are quite divergent in some parts of the curve, from the theoretical values, especially in the case of the lower values, the last traces of carbon dioxide being always much more difficult of absorption by dilute alkalies.

The automatic pipette was made for us in a most satisfactory manner by Emil Greiner, of New York. The Fitz "shakers" may be obtained from the L. E. Knott Apparatus Company, Boston.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Boston, Mass., March, 1901.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

AN APPARATUS FOR RECORDING ALTERNATING CURRENT WAVES.[1]

BY FRANK A. LAWS.

THE apparatus forming the subject of this communication was constructed at the Rogers Laboratory in 1898, and has proved of sufficient value to merit a short description. In brief, the arrangement gives us a modification of the "contact method," by which the record is rendered continuous and traced photographically.

The necessary electrical connections are shown in the diagram, Figure 1. K_1 and K_2 are two rigidly connected contact wheels of ebonite. Into the periphery of each wheel are set four brass blocks. These are accurately placed 90° apart. Upon each wheel a brush and collector ring give permanent contact with the blocks. Another brush resting on the periphery of the wheel completes electrical connection as the blocks pass under it. The brushes are so placed that contact is made and broken at K_2 before K_1 closes. The contact wheels are driven by a synchronous motor, which gives one revolution for four complete alternations of the E. M. F. G is a dead-beat galvanometer, and C is an adjustable condenser. The leads a and b are carried to the points between which the P. D. is to be investigated. By inspection of the diagram it will be seen that once on each wave, and at a definite point the condenser C is charged to the potential existing between a and b. As the charge is determined by the breaking of the contact, the blocks may be of sufficient width to eliminate the effect of the jumping of the brushes. Also the resistance at the contact will not be of sufficient magnitude to prevent complete charging of the condenser.

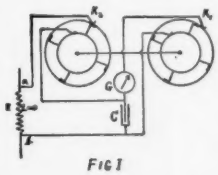

FIG 1

[1] Reprinted from the Proceedings of the American Academy of Arts and Sciences, Vol. 36, No. 17, January, 1901.

The function of K_1 is to discharge the condenser through the galvanometer after K_2 has broken circuit. The instrument would ordinarily experience a constant deflection, but K_1 and K_2 are rigidly connected and mounted on a radial arm, which is geared to the shaft so that it moves very slowly. The effect is to move gradually the contact point over the wave. The deflection of the galvanometer will at any instant be proportional to the P. D. between a and b at the instant of breaking at K_2, or in other words, the deflection follows the wave form.

The actual arrangement is shown in Figure 2 where the contact device, the synchronous motor, and the direct current motor used for starting the apparatus will be seen. By use of worm gearing the wheel

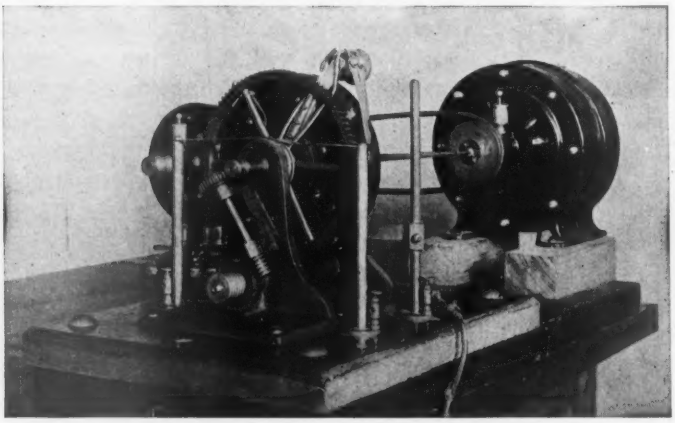

FIG. 2. — ARRANGEMENT OF THE APPARATUS.

train necessary for moving the brushes is made very compact; the reduction for the instrument shown is 7200 to 1.

I have found Sullivan's Universal Galvanometer to be a most satisfactory instrument for use with the apparatus. This galvanometer, of the D'Arsonval type, has a carefully balanced coil, so that it is not very susceptible to mechanical disturbances; also the magnetic damping is most carefully adjusted. The instrument is not of great sensitiveness, but owing to the stiff suspension the zero is perfectly definite.

The camera used for recording the curves is shown in Figure 3. The plate is contained in an ordinary plate holder. This is moved ver-

tically by a fine wire which is wound on a drum, seen in Figure 2, just in front of the lower worm-wheel. This drum can be thrown in at pleasure by a pin clutch. The slide of the plate holder is held stationary by a pin, so that the plate is exposed as the holder is drawn up.

The front of the camera, shown removed, is provided with a narrow slit about $\frac{1}{100}$ of an inch wide. In front of it are projecting lips 9 inches long and $\frac{1}{8}$ of an inch apart. They are blackened within, and serve effectually to shut out extraneous light, and thus prevent fogging of the

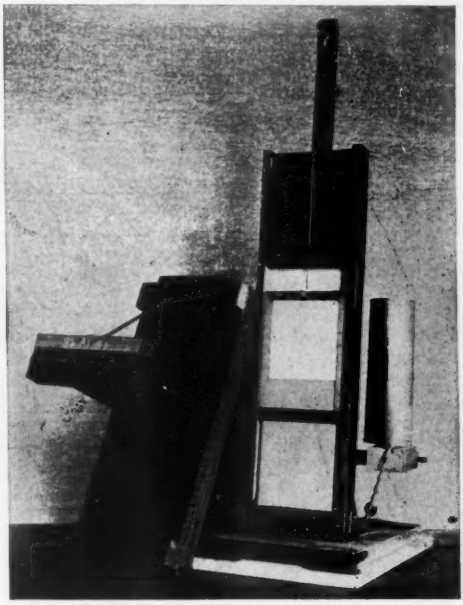

FIG. 3.—CAMERA FOR RECORDING THE CURVES.

plate The spot of light used was the sharply focussed image of the filament of an incandescent lamp. An alternative arrangement is to use a plate of ground glass in the holder, and to have a straight-edge fastened across the guides. It is then easy to keep the point of a pencil in contact with it and upon the spot of light.

The arrangement described is of course a device for obtaining the average wave, and unsuitable for recording transient phenomena. The time taken in recording a wave at 120 cycles per second is about $1\frac{1}{2}$ minutes.

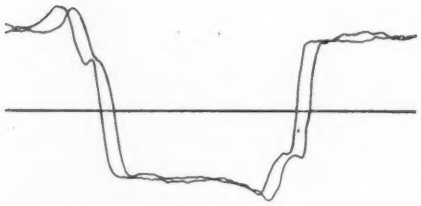

FIG. 4. — Potential difference between the carbons of an enclosed arc, in series with reactive coil.

The curves were taken about 1 minute apart with a view to testing the concordance of the readings.

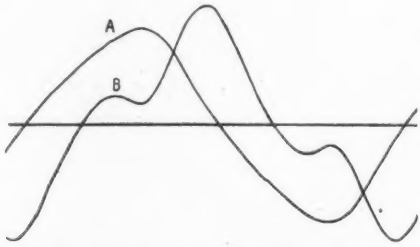

FIG. 5. — *A*, potential difference between the terminals of a small alternating current motor. *B*, current through motor.

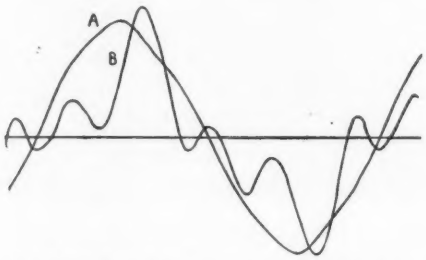

FIG. 6. — Curve *A* is E. M. F., and *B* is current in one phase of a quarter-phase synchronous motor running idle with the field adjusted for minimum current. Source of power was a three-phase dynamo with phasing transformers arranged on the Scott system.

The adjustable condenser allows one to adapt the apparatus to varying conditions, so the E. M. F. curves may be taken directly, and the current curves by the use of a drop wire, as indicated in Figure 1. In starting the arrangement it is very easy to determine when the proper speed for synchronism has been attained by watching the spot of light, or by listening to a telephone which is inserted in place of the galvanometer. With the latter one hears slow beats as the contact moves over the wave. On page 108 are given some examples of the records obtained with the device.

ROGERS LABORATORY OF PHYSICS,
June, 1900.

TYPHOID FEVER AT NEWPORT, R. I., IN 1900, AND ITS RELATION TO DEFECTIVE SANITATION.

By CHARLES-EDWARD AMORY WINSLOW, S.M.

The number of cases of typhoid fever reported to the sanitary officials of the city of Newport, Rhode Island, began to be excessive early in September of the year 1900. Week by week the disease spread, and about the middle of October the local authorities resolved to call in expert assistance. Specimens from certain sources of water-supply which had fallen under suspicion were sent to the Massachusetts Institute of Technology for examination, and were referred to Professor W. T. Sedgwick. At Professor Sedgwick's request, and under his general direction, I undertook the investigation of the outbreak, and I desire at the outset to express my thanks for his advice and assistance in its prosecution. I wish also to acknowledge the cordial coöperation of Dr. R. E. Darrah, of Newport, and of many other persons who aided me in the study of the conditions on the spot.

I. Prevalence of the Disease in Previous Years.

The amount of typhoid fever in Newport of late years has not been excessive as compared with that in other American cities. The records for the last five years are summarized in the following table, the reported cases having been obtained from the records of the Newport Health Office, and the deaths from the Registration Reports of the State of Rhode Island.[1] I have calculated the population for the years between the State Census of 1895 and the National Census of 1900, on a geometrical ratio.

[1] The figures for 1899 were obtained through the courtesy of Dr. Gardner T. Swarts, Registrar of Vital Statistics.

TABLE I.

TYPHOID FEVER IN NEWPORT, 1895–1899.

Year.	Population.	Reported cases of Typhoid Fever.	Deaths from Typhoid Fever.	Death rate per 100,000 population.
1895 . . .	21,537	32	9	41.8
1896 . . .	21,828	29	7	32.1
1897 . . .	22,124	21	1	4.5
1898 . . .	22,423	34	6	26.8
1899 . . .	22,727	52	9	39.6

A comparison of the last column in this table with the death rates from typhoid in other New England cities, shows that Newport has not suffered more severely in the past than have those municipalities whose general conditions are fairly comparable with her own. The figures for the other cities, in Table II, are taken from the monograph on Public Hygiene and State Medicine, prepared by Dr. S. W. Abbott for the United States Commission to the Paris Exposition.

TABLE II.

DEATH RATE FROM TYPHOID FEVER PER 100,000 POPULATION, IN FIVE NEW ENGLAND CITIES, 1895–1898.

City.	1895.	1896.	1897.	1898.
Newport, R. I. . . .	42	32	5	27
Providence, R. I. . .	31	27	15	24
Boston, Mass. . . .	32	31	33	35
Fall River, Mass. . .	33	27	33	21
Worcester, Mass. . .	25	14	14	12

II. EXTENT OF THE OUTBREAK.

It will be noted on inspection of Table I that the number of reported cases of typhoid fever had risen in 1899 to 52, as compared with an average of 29 for the four years next previous. This increase was really even more marked than is indicated by these figures, because, of the 34 cases reported in 1898, 12 were brought to town from Camp

Meade and Montauk Point. There were then twice as many indigenous cases in 1899 as in 1898, and in 1900 the increase proceeded in almost a geometrical progression. The number of reported cases was 127, of which number 108 were of later date than September 1. The weekly distribution of cases is shown in Table III. The dates of cases prior to November 20 were fixed by the day on which the patient took to bed. For the subsequent cases, only the dates of the physician's report of the cases were available.

TABLE III.

WEEKLY DISTRIBUTION OF CASES DURING THE YEAR 1900.

Week Beginning.	Cases.	Week Beginning.	Cases.	Week Beginning.	Cases.
Jan. 15 . . .	1	Aug. 13 . . .	1	Oct. 22 . . .	5
Mar. 19 . . .	1	Aug. 20 . . .	2	Oct. 29 . . .	4
Apr. 23 . . .	2	Aug. 27 . . .	4	Nov. 5 . . .	5
May 21 . . .	2	Sept. 3 . . .	6	Nov. 12 . . .	4
June 4 . . .	1	Sept. 10 . . .	4	Nov. 19 . . .	3
June 11 . . .	2	Sept. 17 . . .	9	Nov. 26 . . .	3
July 2 . . .	1	Sept. 24 . . .	14	Dec. 3 . . .	7
July 9 . . .	1	Oct. 1 . . .	19	Dec. 10 . . .	2
July 23 . . .	1	Oct. 8 . . .	11	Dec. 24 . . .	2
Aug. 6 . . .	2	Oct. 15 . . .	8	Total	127

The number of deaths from typhoid fever during the year was 18, giving a ratio to the population, which according to the Census of 1900 is 23,034, of 78.1 per 100,000. The relation between this outbreak and the amount of typhoid fever prevalent in previous years is seen more clearly from the accompanying diagram, Figure 1, which shows the distribution of cases by months for the past five years.

III. CONDITION OF THE PUBLIC WATER SUPPLY.

The first possible cause which suggested itself to the public in relation to the large excess of typhoid fever in 1900, was the city water supply, and this theory spread the more widely because the Newport water had been highly colored during the late summer, and characterized

by a strongly marked mouldy or grassy odor. This water, which is supplied to the city by the Newport Water Company, is derived from Easton's Pond, a shallow body of water covering about 250 acres to the northeast of the city, and separated into a northern and a southern basin by an artificial causeway. The supply is taken from the more southerly of these reservoirs, and is passed through rapid mechanical filters, with the addition of alum as a coagulant, before entering the force main. This filtration was not, however, carried on with sufficient care to remove the Algæ, which at the time of my visit made the water of the lower basin resemble a sort of gray-green soup. I found in the effluent

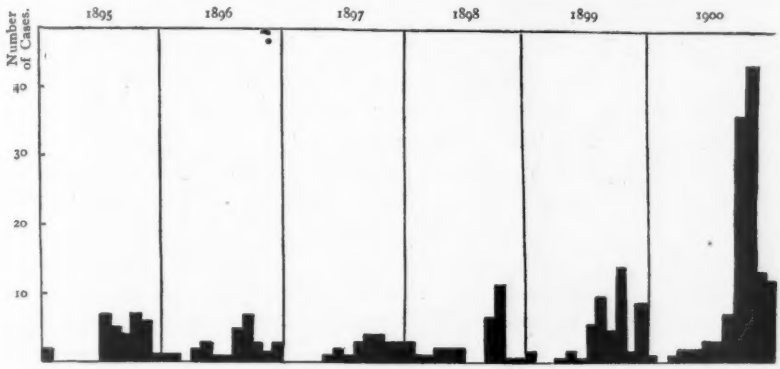

FIG. 1. — REPORT CASES OF TYPHOID FEVER IN NEWPORT, R. I., BY MONTHS, 1895–1900.

from the filter plant, filaments of Anabæna and entire colonies of Cœlosphærium, two members of the group of the Cyanophyceæ which have perhaps caused more trouble to water-works superintendents than any related forms. It was presumably to these two forms that the unpleasant taste and odor of the water had been mainly due.

From an epidemiological standpoint, however, a brief inspection of the reservoirs gave no evidence of any serious defects. The south basin of Easton's Pond is protected from surface pollution by a ditch which surrounds it and drains to the ocean. The watershed of the north basin is thinly settled, and the reservoirs are so large as to secure the purifying effects of storage in a considerable degree. A specimen of the water taken from a tap in the town on October 13, gave the following analysis, which, though it shows a large amount of albuminoid ammonia, due perhaps to the vegetable growth, and an excess of nitrates, does not indicate the presence of recent sewage pollution.

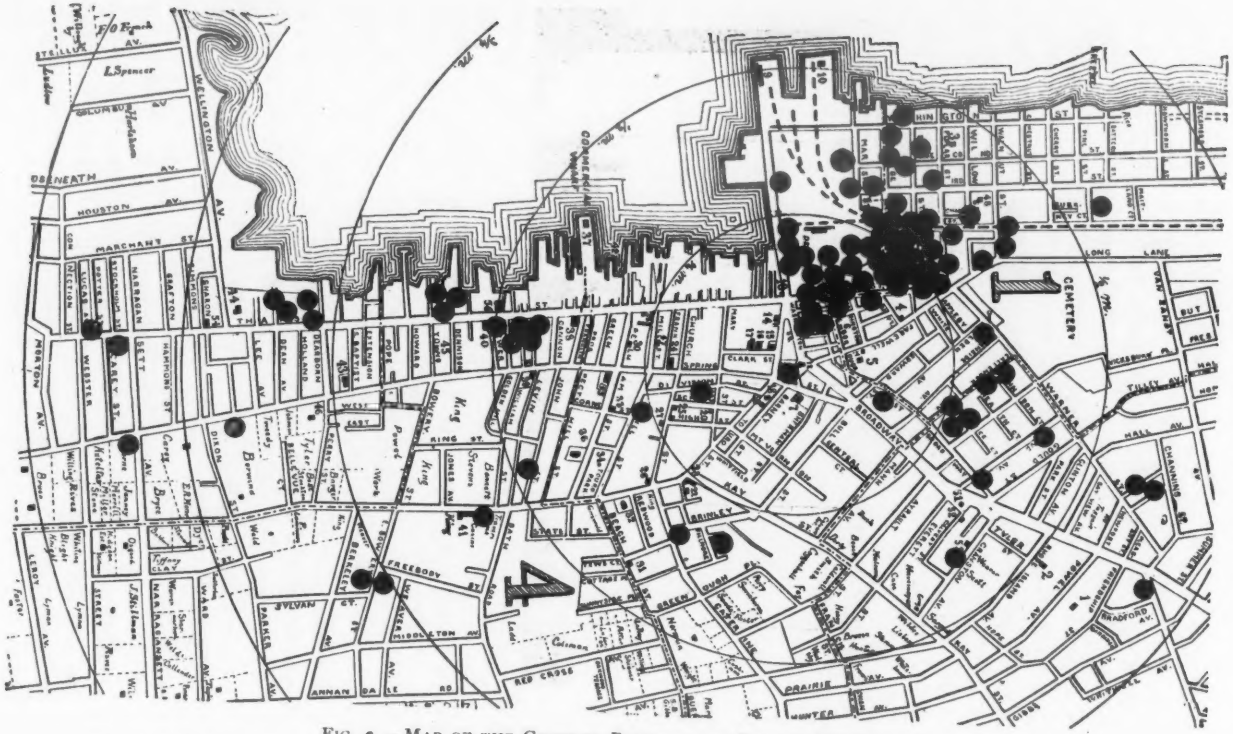

FIG. 2. — MAP OF THE CENTRAL PART OF THE CITY OF NEWPORT.
The black circles indicate the location of the cases of typhoid fever reported between August 1 and November 20, 1900.

SAMPLE OF NEWPORT TAP WATER COLLECTED OCTOBER 12, 1900.
(Parts in 100,000.)

Turbidity.	Sediment.	Color.	Odor.	Free Ammonia.	Alb. Ammonia.
Very slight.	Very slight.	.35	Dist. veg. Mouldy.	.0018	.0372

Chlorine.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Hardness.	Bacteria per c.c.	B. coli.
1.86	.0000	.0350	2.6	334	0

Conclusive proof that the typhoid fever was not due to the water supply was found, however, in the geographical distribution of the cases. In a water epidemic the cases appear in all quarters of the town, following the lines of the water mains, being perhaps thickest near the distributing reservoirs, but otherwise occurring about equally in all districts. It is impossible that a general infection carried equally to all parts of a city should produce a large number of cases in a single neighborhood and pass by others similarly circumstanced. In Newport, however, as will be seen by an inspection of the accompanying plans, the great majority of the cases occurred in a limited district of the first ward, twenty-six of them within a radius of 300 feet. On Figure 2, which represents the thickly settled portion of Newport, the cases of typhoid fever reported between the 1st of August and the 20th of November are indicated by the black dots. A moment's study of this map is sufficient to show that some more local source of infection than the city water must be sought.

IV. THE BRIDGE STREET WELL.

The well popularly known as the "Jones Well," at 26 Bridge Street, which formed the supplementary water supply of the affected district, and was frequently used in preference to the city water on account of the coolness of the former, and the color and odor of the latter, was the next object of suspicion. It seemed at first that the cases were distributed so evenly over so long a period of time as to make it improbable that any single cause had been instrumental in all of them. Investigation soon showed that many of the patients had not drunk the well water. It also, however, made it apparent that the cases in which well water had been used, were those most strictly localized in time. While the other cases straggled along rather evenly from week to week, those of this class were grouped together, beginning with one or two isolated cases early in September, becoming numerous after the 15th, reaching a maximum of six cases on the 29th, and declining again after October 7. The well was closed and boarded over in accordance with

my recommendation on the 15th of October, and after October 29, or the lapse of the average incubation period for typhoid fever, only three cases have occurred in the community using the Jones Well, and all three were return cases traceable to personal contagion. (See Figure 3.)

We find then, thirty-eight cases of typhoid fever occurring between September 16 and October 23 in a limited district and among a population using a special source of water supply. This source of supply was a shallow well about 10 feet deep, and 8 feet in diameter, with sides of uncemented stone and a covering of planking, upon which those who

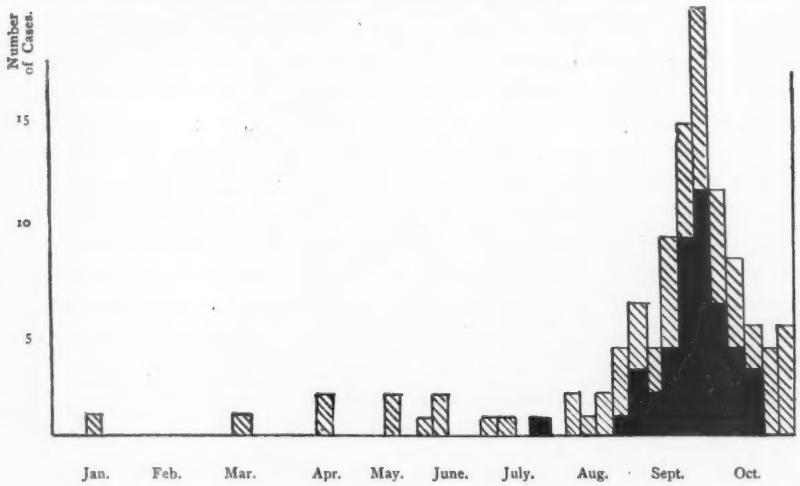

FIG. 3. — REPORTED CASES OF TYPHOID FEVER IN NEWPORT BY WEEKS, DURING THE FIRST TEN MONTHS OF THE YEAR 1900.

The black columns indicate those cases in which the Bridge Street well had been used for water supply, the cross-hatched columns represent those cases in which there was no such history.

used the water stood while operating the primitive wooden pump by which it was raised. The watershed, sloping gently to the east, included some twenty privy vaults within 400 feet, the nearest being in the rear of Numbers 28 and 26 Bridge Street, respectively 25 feet and 60 feet to the southward (Figure 4). The water level in the well was about 2 feet below the surface of the ground, so that the material from the vaults could pass laterally through the filth laden and water soaked soil without any downward filtration whatever. The following analysis of the well water fully confirms the conclusion drawn from a sanitary inspection — that the well was grossly contaminated.

SAMPLE OF WATER FROM WELL AT 26 BRIDGE STREET, COLLECTED OCTOBER 12, 1900.
(Parts in 100,000.)

Odor, cold.	Odor, hot.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
F. musty.	None.	.0248	.0068	8.30

Nitrogen as Nitrites.	Nitrogen as Nitrates.	Hardness.	Bacteria per c.c.	B. coli.
.0500	.8500	12.11	6100	Present.

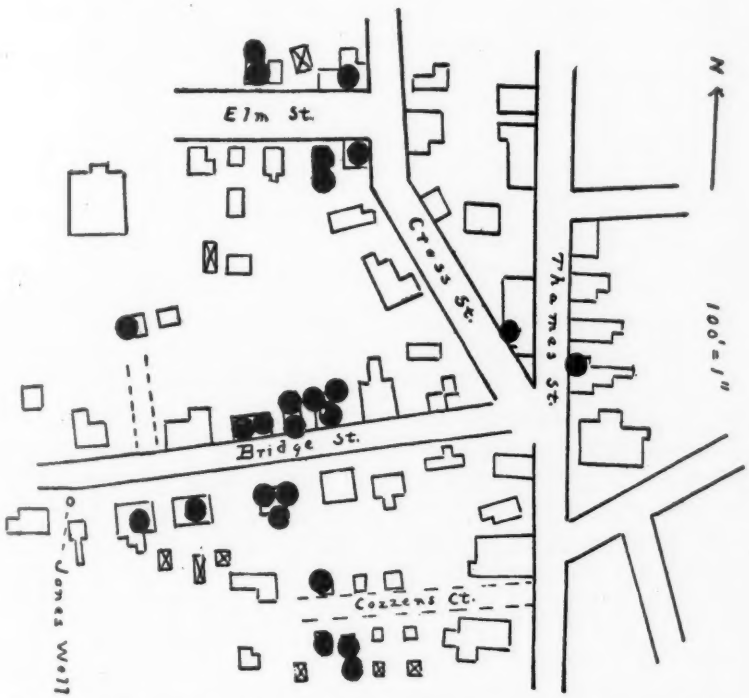

FIG. 4. — SKETCH PLAN OF PART OF THE WATERSHED OF THE BRIDGE STREET WELL.

Each black circle indicates the occurrence of a case of typhoid fever, between August 30 and October 30, 1900.

If typhoid germs can ever be carried through the earth, they could be carried from the dejecta of a typhoid patient in one of the neighboring vaults to a well of this character. That such dejecta were present is certain. On August 31, there was a case of typhoid fever at 11 Bridge Street, with a vault about 200 feet northeast of the well, and on September 3, there was a case in Cozzens Court with a vault 300 feet

southeast, (see Figure 4). It is easy to conceive, especially as I found that the excreta had not been disinfected in these early cases, that a slight amount of infective material may have found its way from one of these sources to the well, and caused the first few cases. One of these first cases, already sick with what proved later to be typhoid fever, left 28 Bridge Street on September 15. The vault in which the excreta of this patient were received was only 25 feet from the well; and it is still easier to conceive that infection passed through this short distance and caused the later outbreak which culminated with twelve cases in the week of October 12. In some such way, either by percolation through the open soil or by accidental infection from the top, the well, in my judgment, became infected, and caused about one-third of the cases making up the total outbreak.

V. Other Possible Vehicles of Infection.

The fact that no large number of typhoid fever patients had a common milk supply, excludes that important factor in the transmission of disease. Among the one hundred and ten cases investigated, (up to November 20), there were thirty-one milkmen; the greatest number of affected families on any one route was five, and in these the cases did not occur simultaneously. Two apparently sporadic cases may, however, have been due to this cause. Case Number 30 was a milkman supplying from twenty to thirty families in a district quite outside the region where the main epidemic was localized. He cared for the entire business in person, as well as for the delivery of the product. On September 15, he took to his bed with typhoid fever; every precaution was at once taken for the future, and the milk business was put in charge of another person not connected with the household. On October 2 and 6, however, two of the customers on this route fell ill, the disease in one instance terminating fatally. It is possible that these two cases may form a miniature milk epidemic such as might often occur without attracting attention.

A large proportion of the typhoid patients had purchased ice-cream from a shop kept by a dealer on Bridge Street, and I was inclined at first to consider this fact significant. It proved, however, that this was the popular source of supply for the entire neighborhood, the healthy as well as the sick. Of the thirty-one cases among the customers of this shop, between September 1 and November 15, eighteen were also users

of the Jones Well water, and the thirteen remaining were so widely scattered in time as to rule out the possibility of a common source of infection. Furthermore, an investigation of the shop in question, and of the origin of its various supplies failed to reveal any apparent opportunity for contamination.

A majority of the households stricken by the epidemic did not use ice. Those who did so, obtained it from one of two companies, both of which have delivered during the summer a mixed supply of artificial ice and natural ice, supplied by the Boston Ice Company. The cases among the ice users did not occur in greater number at any special period so as to warrant any suspicion of this supply as a cause of the epidemic; and hundreds of persons in other districts of the city used ice from the same sources without ill effects.

Finally, there was no common source of supply for green vegetables among the typhoid patients, and only a very few of them had been in the habit of eating raw shell fish.

VI. Influence of Sanitary Conditions.

No common cause was then found for the residuum of cases not connected with the Bridge Street well. This is exactly what one would expect after an examination of Figure 3; for if the Jones Well cases are eliminated, it appears that the fever did not strike a sudden blow at a definite time, but has exercised a more or less constant pressure since early in August. Not a week between August 20 and December 17 passed without at least two cases outside of the well users, and in only two weeks did the number of such cases exceed five. The well, if my conclusions are correct, caused an epidemic in the last part of September and the beginning of October; the other cases formed not a sharp epidemic outbreak, but rather such a slow succession of isolated cases as the older sanitarians termed "endemic." This term has been so misused, so associated with the idea of some mysterious miasm inherent in a geographical region, that it has fallen into deserved disrepute. It is, however, vital for the epidemiologist to distinguish this process clearly from the infection which reaches a number of persons at once through a single medium, such as water or milk. I have ventured to coin the term *prosodemic*, "through, or among, the people," for this form of disease which progresses gradually from person to person by routes which, whether direct or indirect, are different for each individual case.

The term "epidemic" I should restrict to that special case in which circumstances permit the transfer of infection to a large number of persons through the same medium, and at approximately the same time.

The methods by which prosodemic typhoid may spread are almost infinite. The last link in the chain is, in most cases, some sort of food or drink; and the food becomes directly infected, in many instances, from the hands of the typhoid patient or of his unprofessional attendants. The transmission of typhoid fever on a large scale by water and milk, has led sanitarians to minimize unduly the direct personal element in its etiology; but the fact that two trained nurses were stricken down during the year in Newport, recalls the possible importance of this factor. Another mode of conveying disease, to which we have learned to attribute an increased significance within the last few years, is the carriage of infected matter by insects; and there can be no doubt that many mysteriously sporadic cases of typhoid fever are conditioned by the passage of a fly from an infected vault to an unprotected table or an exposed larder. At the other end of the chain, however, there is in almost every case of prosodemic infection some disregard of sanitary cleanliness. Hands, insects, and food can only become contaminated when infective material has not been properly removed and cared for. An epidemic affecting a great number of persons through water, milk, or oysters, may be due to a single act of carelessness or ignorance. It is only, however, among a dirty population in unsanitary dwellings that typhoid fever becomes actively contagious. It is, therefore, instructive to note that of the premises upon which typhoid developed in Newport, I inspected eighty-one, and found that forty-two were provided with privy vaults, and only thirty-nine connected with the sewer; and of the former, twenty-one at least were in a foul and dangerous condition.

As has been said, the infection by means of filth and fingers, of flies and food, proceeds by a different path and at a different time in each case, and is generally impossible to trace in detail. In certain instances, however, the probable course of contagion from person to person is clearly indicated; a few such chains of evidence I have collected in the Newport outbreak, of which the following selected examples are perhaps the best.

1. Case Number 76, a teamster, exposed in his work to many opportunities of infection, developed the disease at his home on Harrington

Street, October 10. On October 23, or after the lapse of two weeks, the average period of incubation for typhoid fever, case Number 95, a fellow teamster, boarding at the same house fell ill. On December 6, a third case, Number 119, was reported from the same house.

2. On August 12, case Number 14 developed in a house on Thames Street, the patient being a little girl who had come from New York State two weeks previously, probably bringing the infection with her. On August 28, her nurse, case Number 18, was taken sick; and on September 17, her grandmother, living in the same house, fell ill in turn with the disease.

3. Case Number 80, a domestic employed on Powell Avenue, left that place September 25, to nurse a cousin who was suffering from "diarrhœal trouble," on Bridge Street, opposite the Jones Well and in the thick of the epidemic. On October 9, she returned to Powell Avenue, and on October 12 she took to her bed with typhoid fever. She is said not to have drunk the well water while in Bridge Street.

4. Case Number 84 was a boy of thirteen, living in Spruce Court, who sold papers in the Bridge Street district, and probably contracted his disease from the well water. He fell ill on October 14. His mother worked for a family across the way, and went over, to assist in the preparation of the food, from the bedside of the invalid. On October 31, case Number 99, a young woman in the house where the mother worked, fell ill with the fever.

5. On October 9, case Number 75, a girl in a family on Long Wharf, developed the disease, probably derived from the Bridge Street well. On November 14, her sister, on November 16, her mother, on November 21, her brother, and on November 24, another inmate fell ill, although by this time the well had long been closed and the general epidemic had subsided. The premises in this, as in most of the other instances where return cases occurred, were dirty and ill-kept.

6. On the 15th and 19th of October, two cases occurred among the customers of a steam laundry on Mill Street. On the 9th of November, case Number 104 developed, the patient being a young man engaged in that laundry in the process of sorting the clothes.

7. Case Number 21 was a young lady living in Thames Street very near Bridge Street and the infected district, who was taken sick September 1, the source of infection not being apparent. Her niece, a little girl of seven, who lived in Channing Court, in another quarter of the city, but spent much time with her aunt in Thames Street, developed

the disease at the same time, and was sent home to Channing Court, where her brother, ten years old, case Number 53, fell ill on September 29, and her sister, aged three, case Number 82, followed on October 13.

VII. Lesson of the Outbreak.

After the closing of the Bridge Street well, the typhoid outbreak did not again become severe, and with the onset of cold weather there was a gradual decrease in the number of cases due to contagion, until in the last two weeks of December, there were only two cases reported, and in January, 1901, there was only one case. With rising temperature, however, the typhoid rate has also began to rise, as is its wont. In February there were three cases, and in March, four; a small number, but large enough to be menacing, in view of the fact that there were only three cases in these two months last year.

The way in which the typhoid germ survives the winter and begins the steady increase which culminates in an October maximum, is well shown in the Newport records. This bacterium does not ordinarily live very long, at least in large numbers, outside the human body, under the damaging effects of cold, light, dryness, poor food, etc.: but in heaps of excrement there is reason to believe that it may survive for many months. From germs preserved in this way it seems likely that the 1900 outbreak started. Cozzens Court is a short street parallel to Bridge Street, inhabited mostly by negroes, and its vaults and the whole surroundings were in an exceedingly filthy condition. There were four cases of typhoid fever in this court in 1899, the first on August 11, the second and third at Number 7 on August 26 and September 26, and the fourth at Number 2 on October 27. The first case to occur in the Bridge Street neighborhood in 1900 appeared with no apparent outside source of infection at Number 7 Cozzens Court on July 12; the second at Number 2 Cozzens Court on July 27. Of the two cases to which I attribute the contamination of the Jones Well, the first was at 11 Bridge Street, a stone's throw from the cases mentioned, and the second was again at Number 2 Cozzens Court. The same thing has apparently happened during the winter just past. It can hardly be a coincidence, that of the four cases reported in March, 1901, two are from a house on Thames Street provided with a privy vault in which there was a case of typhoid fever in October, 1900.

To prevent the preservation of typhoid germs through the winter, and the sowing of them broadcast during the summer, there are two remedies — their destruction or the removal of the vehicles by which they are spread. First, then, disinfection suggests itself as an available weapon; and I submitted to the Newport authorities a complete schedule for the treatment of excreta, of clothing and bedding, and of infected walls, floors, and woodwork. Much good work was done in this direction. Most of our processes of disinfection are, however, incomplete, and even if every typhoid bacillus present at a given time could be exterminated, the filth which furnishes means for keeping alive and distributing imported germs would remain a constant menace. The one vital fundamental remedy is sanitation — the closing of shallow wells, the cleaning of the streets and yards, and in particular the removal of the vaults which may preserve typhoid germs in active condition for long periods, which pollute the ground and ground-water in their neighborhood, which foster habits of personal uncleanliness, and favor the transmission of disease both by contagion and by the agency of flies and other insects.

It is because it calls attention to the sewell-known but often forgotten dangers that the Newport outbreak is of interest. Newport is no worse than many American cities. We have been right in considering water as the most important vehicle of typhoid fever. That lesson has now been learned, and most of our cities put sufficient value on human life to protect their sources of drinking water. The next most important vehicle of typhoid fever, in my opinion, is filth, and to this our attention should be increasingly turned. The sewer-gas fetich of the British sanitarian has led him into some absurd excesses; but it has worked most effectively for civic cleanliness. Few English, and fewer German communities would endure the typhoid death rates which weigh year after year upon the best American cities. What is the reason for our excess; is it infected water, milk, and shell-fish, or merely filth? It is incumbent upon us to find out. For the typhoid death rate is the reciprocal index of civilization.

THE TRIPOLITE DEPOSIT OF FITZGERALD LAKE, NEAR ST. JOHN, NEW BRUNSWICK.

By W. O. CROSBY.

Among the numerous deposits of tripolite in the fresh-water lakes and swamps of the Maritime Provinces, some of which are, no doubt, destined to prove of considerable economic importance, it would probably be difficult to find a deposit of considerable magnitude which is, on the whole, of more special interest to the student of geology than that of Fitzgerald Lake. In some respects this deposit is unique, and it is particularly so in the simplicity of its history, which permits us to regard it as a type of which many other deposits are more or less widely divergent variations. The essential conditions of the accumulation of a notable deposit of organic silica in a state of approximate purity are exhibited in Fitzgerald Lake so free from complications as apparently to justify placing on record the results of a study made several years since, although the explanation which the facts have suggested may be wholly lacking in originality.

Fitzgerald Lake is between seven and eight miles northeast of St. John, on the Loch Lomond road and on the headwaters of Little River. It has an elevation of 290 feet above high tide, and is bordered by a wooded plain of coarse gravel (modified drift). On the east and south sides of the lake the land rises 30 to 50 feet to form a winding ridge (probably an esker) which encloses Latimer Lake, the chief reserve of the St. John water supply. Latimer Lake, which is naturally tributary to Mispeck River, had an elevation of 302 feet before its outlet was dammed, and its outflowing waters turned through a low cut in the ridge down through Lake Fitzgerald into Little River. On the northwest, the plain of modified drift enclosing the basin of Lake Fitzgerald falls gently away toward Little River, descending 70 feet in one-fourth to one-half mile. Fitzgerald Lake is reached on the north side by a short branch from the Loch Lomond road, and a road following more closely the valley of Little River passes within a short distance of the south side of the lake.

Fitzgerald Lake was drained several years ago by the cutting of a shallow trench across the narrowest part of the bordering plain, and is

now a grassy meadow, with the overflow from Latimer Lake passing through one corner of it in a narrow artificial channel. The area of the lake is 74 acres, and it is estimated that approximately 60 acres are underlain by the tripolite. Its outline is an irregular oval, a broad reëntrant curve indenting the northwest side; and here the bottom is of a rough stony character for a breadth of 100 to 200 feet, the depth having been insufficient to permit the formation of any deposits. Considering its area, the lake was very shallow, the maximum depth having been less than five feet. The greater part of the lake is now well grassed over, the grass forming quite a strong turf, over which with due care it is possible to walk without breaking through. The tripolite is practically the surface deposit; in other words, it is not covered by clay or peat or anything except this thin turf, and considerable patches of the tripolite are entirely bare, even of grass.

With suitable lengths of one-half-inch gas pipe, a series of soundings was made across the lake in different directions to test the depth and quality of the tripolite, and in this way it was proved, not only that the deposit has a considerable depth, but that the tripolite is continuous from the surface downwards; that is, it is not interstratified with clay or peat. In some cases the pipe struck a hard, stony bottom, and in others penetrated a firm, semi-hard form of the tripolite, a bottom layer which has probably no great thickness. Above this layer, which proved on examination to consist largely of quartz flour, the tripolite is uniformly soft and slimy, the gas pipe passing through it almost of its own weight. The surface of the bog, or lake bottom, is very quaking, and but for the density (specific gravity) of the underlying tripolite jelly, walking over it would be dangerous. The thickness of the pure or approximately pure tripolite varies from a foot or less near the edge of the deposit to ten or twelve feet in the central portion, and an average depth of five feet seems a safe estimate. It is very clear that the deposit is all tripolite down to the level where it begins to change gradually into the quartz flour, which becomes at last so compact and firm that the gas pipe was with difficulty forced into it, and the quartz flour shades off at some points into ordinary fine sand. The covering of grass grows directly on the tripolite, and it is evident heretofore that the lake has always been flooded, for there is nowhere any appreciable amount of peat over the tripolite. This lake basin must have been originally a large and comparatively shallow kettle-hole, having a maximum depth of twenty or possibly twenty-five feet in the plain of modi-

fied drift; and it is now filled nearly to the brim with this slowly formed, organic deposit, which, in its present super-saturated condition, is like a quaking siliceous jelly, with only a thin cover of turf, and with a substratum of quartz flour from one to ten feet in thickness. The tripolite is naturally of a gray to dark brown color, due to the presence of organic matter, which is readily burned out; and after calcination the material is nearly white, being but slightly tinged with iron oxide.

An analysis of a calcined sample gave the following result:

Soluble silica	82 per cent.
Insoluble silica in the form of impalpable quartz flour . .	17.5 per cent.
Clay, iron oxide, etc.	traces.
	99.5 per cent.

In searching for the explanation of this deposit it is important to note: that the catchment area, or watershed, of this basin (kettle-hole) is very limited; that there were naturally, or before the diversion of Lake Latimer, no tributary streams; that the surface is of such character (chiefly coarse gravel) as to afford little or no rain wash, especially as it is, and probably always has been, covered with forest and a thick layer of vegetable mould; and that the conditions are very unfavorable for the introduction of wind-borne dust. Mechanical silt has thus been almost wholly excluded, and a continuous cover of water has prevented the formation of peat.

Water percolating through the layer of vegetable mould over the surrounding surface has penetrated the underlying gravel, where the carbonic and organic acids with which the water is now charged, have slowly decomposed the silicate minerals (feldspar, hornblende, etc.) of the numerous pebbles of granite, felsite, diorite, etc., forming carbonates of the alkalies and alkaline earths and liberating an equivalent amount of silica, which, being soluble in water holding alkaline carbonates, is carried in solution into the lake, where it is appropriated by the diatoms with which the waters swarm.

An alternative hypothesis is based primarily on the well established fact that several of the humus acids, and notably azohumic acid, are efficient solvents of silica, which will be precipitated when these acids are converted by oxidation to carbonic acid, by the oxygen exhaled by diatoms, as by all other forms of vegetable life. This explanation would enable us to derive silica directly from quartz, and not exclusively from the silicates.

The process is probably essentially chemical at every step, although the precise nature of the reaction of the organism upon its medium, determining the deposition of silica in or upon its body, is still undetermined. This slow process of the leaching of silica from the surrounding gravel through the agency of decaying organic matter, and its precipitation by the diatoms in the forms of their exquisitely fashioned frustules has been uninterrupted for thousands of years; until the resulting deposit of tripolite completely fills the basin of the lakelet. Meanwhile, but little sand and clay have been washed from the shores of the lake by its feeble waves, and the surrounding forest has protected the lake from wind-blown dust; but the deposit of nearly pure tripolite is, under existing conditions, being overspread by a layer of peat. The uncompacted and quaking consistency of the tripolite has probably tended to keep it pure by permitting such mechanical detritus as did find its way into the lake to settle to the bottom, and thus, probably, the substratum of quartz flour blending upwards with the tripolite has been chiefly formed. A further condition essential to the formation of tripolite and realized here, is the absence of an outflowing stream. Like so many of our kettle ponds and lakes, this is a closed basin from which the water escapes only by seepage and evaporation. The silica leached from the surrounding gravel and the organisms essential to its precipitation in the solid form are thus retained in the basin; and the cycle of chemico-organic erosion and deposition is completed in a limited area; for through the combined agency of decaying organic matter on the land, and living organisms in the enclosed and stagnant, but limpid, water is effected a gradual transfer of silica from the hard, insoluble silicates of the gravel and its deposition in a pure but hydrated and opaline form in the bowl-like depression left by the melting of a buried remnant of the great ice-sheet.

ON THE APPLICATION OF BACTERIOLOGY TO CERTAIN ARTS AND INDUSTRIES.[1]

By SAMUEL C. PRESCOTT, S. B.

During the last four decades of the Nineteenth Century the advance of scientific knowledge brought to light many new and interesting discoveries, not the least important of which were in the domain of biology. Of greatest value, perhaps, was the work upon the micro-organisms, and especially upon that class of micro-organisms known as bacteria, and which led to the establishment of the germ theory of disease, which has practically revolutionized the art of medicine, and has been the creator of the science of sanitary engineering.

It would be impossible to overestimate the value of the discoveries made in this field, and it is not surprising to find that interest in the bacteria has in years past centred largely in their sanitary and pathological relations, although it has long since been shown that the disease-producing species constitute but a small proportion of the bacteria now known.

It is of interest, however, to bear in mind that the discoveries which proved of most value in establishing the germ theory of disease were made along lines affecting, not the health of any people, but its economic and industrial relations. The work of Pasteur on undesirable fermentations of wine and beer, and his later work upon the silk-worm disease, which seemed likely to bring utter ruin to the silk industries of France, demonstrated in a most efficient manner that certain specific organisms endowed with definite morphological and physiological characters gave rise to specific and characteristic troubles or diseases, and led to the theory that each disease and each fermentation has its specific exciting organism. The triumphs which have resulted in preventive medicine have amply proved the significance of this discovery to humanity, and proclaim it perhaps the greatest achievement of the century.

It is not only on the pathological and sanitary sides of the subject, however, that bacteriology has made its advance. The technical side

[1] Read before the Boston Society of Natural History, March 6, 1901.

has not been overlooked, but on the contrary has made gigantic strides, leading to the establishment of experiment stations and laboratories for the investigation of fermentation problems, and for the development of those branches of industry wherein micro-organisms play an important part. To the manufacturer, chemist, or technical man this new subject of industrial bacteriology appeals even more strongly than does the pathological side of the subject, and that popular interest in it is less, is largely because of its recent growth, and because the facts underlying this fascinating branch of applied science have not been sufficiently elucidated.

I desire, therefore, to consider certain phases of the subject of industrial bacteriology, and to show, if possible, how a knowledge of micro-organisms may be applied to productive or manufacturing processes. This can best be done by describing the predominant rôles — both useful and antagonistic — which are played by some of the micro-organisms; useful, when we employ certain species to bring about desired chemical changes; antagonistic, when the growth of the organisms, if unchecked, would give rise to harmful or undesirable substances and thus result in commercial loss. Thus we may consider here the part acted by micro-organisms in the manufacture of vinegar and lactic acid, in baking, brewing, and wine making, in the preparation of skins for tanning, in the dairy and sugar industries, and in certain agricultural processes, and so on through a long list of reactions formerly believed to be purely chemical in character, but now recognized as being intimately bound up with the vital processes of living organisms.

To all these manifold transpositions of organic substances thus produced we give the term fermentation, so that our science of Industrial Biology is in reality a science of fermentation, using this term in its widest sense, for this word has broadened in meaning as the knowledge of such processes has increased, and has far outgrown its original significance. We no longer think of fermentation as merely the transformation of sugar to alcohol and carbon dioxide, but as a term embracing a multitude of chemical reactions, all being alike in the one respect, however, that the ultimate cause is a living cell. Before considering the specific fermentations in detail, some further general statements as to cause and manner of action may be of interest.

Let us first consider the organisms themselves which may be utilized to bring about these fermentations. The industrial bacteriologist deals not only with bacteria, but also with certain other colorless plants or

fungi, for many moulds and yeasts, as well as bacteria, are of technical interest.

Leaving the systematic botanical position out of account for the moment, the above mentioned organisms possess certain characteristics in common. The most striking is, of course, the ability to produce fermentative changes of chemical and industrial significance. Not less important from the point of view of the fermentation chemist and physiologist is the fact that all these organisms may be made to grow in pure cultures in or upon specially prepared nutrient media, and hence their activity and power to induce fermentative changes may be studied with a considerable degree of certainty. As the methods employed for this purpose are modifications of those originally designed for the study of the bacteria, or bacteriological methods, it is convenient to class all the organisms which may be so studied as "bacterial organisms," as has been recently suggested by Professor Sedgwick,[1] when speaking in general terms, although more specifically one would refer to the generic name, or at least to the class name.

Briefly stated, the three classes may be characterized as follows:

The moulds are colorless branching organisms, increasing vegetatively by means of apical growth, and normally reproducing by the formation of spores, either in a special closed body, or sporangium, or in rows like strings of beads with no retaining covering. They occur abundantly on dead organic matter of suitable composition, especially carbohydrate; grow with great rapidity, producing a mycelium, or mass of growth easily visible to the naked eye; and, except under special conditions, give rise to only very small amounts of fermentation products. Grown submerged in sugar solutions, without access of air, they give rise to a vigorous alcoholic fermentation. They prefer an acid medium.

Of greater importance are certain of the *yeasts*, as employed in bread-making, brewing, and wine-making. These are small oval or rounded organisms which increase in numbers rapidly under favorable conditions by a process of budding, that is, a cell produces at one end a little outgrowth, or knob, which develops to nearly the size of the parent cell, and then becomes independent by the formation of a dividing wall, although it may still remain attached to the older cell. The yeasts are especially active as producers of alcohol and carbon dioxide, and upon this activity their industrial value depends. In size

[1] W. T. Sedgwick, "On the Origin and Scope of Bacteriology." Presidential Address before Society of American Bacteriologists. *Science*, January, 1901.

they are intermediate between moulds and bacteria, the smallest known organisms.

Although smaller and presumably simpler, the *bacteria* have much greater diversity of fermenting power, yielding a large variety of substances. Their general appearance is rod or ball-shaped, and their ordinary method of growth is by simple fission, or the splitting of one organism into two. Here, too, growth is extremely rapid when conditions are favorable. Many kinds are able to produce extremely resistant bodies known as spores, whose function is apparently to perpetuate the life of the species during periods when the environment is unsatisfactory for the normal vegetative development.

Along with the increase in our knowledge of the number and varieties of fermentations and ferment organisms has come also a better understanding of the way in which these minute cells are able to carry on their characteristic actions. It has been possible, by careful investigation, to penetrate into the living laboratory, and to find out in an imperfect way the kinds of reagents which the cell uses in its chemical work.

It has for a long time been known that certain cells, as for example those of sprouting grain, were able to bring about the change of starch into maltose and glucose, the process familiarly known as malting. It has also been known that yeast could bring about a similar change from cane sugar to glucose, and that the latter substance was then "fermented" or split into alcohol and carbon dioxide. The power to bring about these chemical changes was found to be due to certain soluble substances of complex nature which could be isolated from solutions containing them, and to which the name "soluble ferments" was first given, but which are now spoken of most frequently as *enzymes*. Similar substances were known to be produced by certain cells in animal organisms, as for example, the pepsin of the gastric juice and the trypsin of the pancreatic juice, which react almost exactly as plant enzymes do. From time to time new enzymes have been discovered, until at the present time there seems little reason to doubt that fermentation as we know and can study it, is entirely the result of enzyme action, although it must ever be borne in mind that the living cell is the ultimate cause since it is the producer of the enzyme. These enzymes, as has already been stated, can be precipitated or otherwise separated from the cells producing them, and in the isolated condition can give rise to the characteristic action which determines the fermentation,

although the powers of the enzyme are in some cases weakened by such separation. The reason for this is, perhaps, because of the crudeness of the methods of preparation to which we have had recourse up to the present time. In fact, we have no way of determining with certainty whether the enzyme as prepared is in a state of purity or not, and the chances are very favorable that our most successful attempts are far from perfect. Moreover, we know that these substances are extremely sensitive to certain chemical compounds, bases and acids, and thus will act only under somewhat limited conditions.

All enzyme action is characterized by the fact that a small amount of the active agent can transform a comparatively large amount of the substance acted upon, and without itself becoming used up or destroyed. Thus it has been shown that in the conversion of cane sugar to glucose a given weight of the diastase can easily transform 100,000 times that weight of sugar, and with no apparent loss to itself. Sometimes the same chemical change can be brought about by purely chemical means; for example, the conversion of cane sugar just referred to can be produced by boiling with dilute acids; or, to take another example, albuminoid substances, which are generally changed to peptones by the action of enzymes, can undergo the same change, to some extent at least, on being treated with steam under pressure. Notwithstanding these facts, there still exists a great difference between this chemical work and the physiological work of cells.

In order to favor chemical reaction one often makes use in the laboratory of very violent means, perhaps a strong acid or alkali, high pressure or a high temperature. To produce, for example, an oxidation process one may use reagents such as nitric or chromic acid or potassium permanganate. As a dehydrating agent, concentrated sulphuric acid, or anhydrous phosphoric acid, or zinc chloride may be used. When one works with living cells, on the contrary, the reactions take place in media of nearly neutral reaction, and the temperature is always moderate and nearly constant. The difference between these two methods of action is most striking. In the living cells there takes place the reaction of bodies which, according to our generally accepted ideas, have only weak affinities. We observe at the same time that substances which we ordinarily regard as very stable are decomposed within such cells with great facility.

Three varieties of chemical action have been recognized among the enzymes; first, and most frequent, a hydration, generally, but not always,

followed by a splitting of the compound into simpler substances; second, oxidation; and third, molecular decomposition into simpler compounds without hydration. Having thus broadly defined the fermentation organisms and the way in which they act, let us now consider in greater detail some of the processes of industrial importance in which these organisms play a part.

We may begin with the alcoholic fermentation, since this is the one which has received the most attention, is of most interest historically, and offers a large field for the microbiologist in dealing with the many problems presented. Four industrial processes may be here considered: brewing, wine-making, fermentation for panification, and fermentation for distillation. In all these certain yeasts are depended upon to give the desired result, and it is recognized that other yeasts or other kinds of organisms might be of great injury in giving rise to by-products of an undesirable nature. Thus, in bakeries, yeast is used to give lightness and a certain texture and flavor to the bread. The mixture of flour and other ingredients is heavily inoculated with yeast and put at a moderate temperature to "rise." Diastatic enzymes in the flour itself bring about the inversion of some of the starch present, and the yeast soon sets up a vigorous alcoholic fermentation, the bubbles of carbon dioxide formed becoming enclosed in the thick dough, and thus making it more or less spongy or porous in texture. The effect of temperature here is very marked; if too high a temperature be used in raising the bread, sourness will result, caused by the fermentation of the sugar, not to alcohol, but to lactic acid, by bacteria which are present in the flour or as an impurity in the yeast. So long as the temperature is kept low enough these act but feebly, partly because of the antagonistic action of the yeast, and partly because of the fact that their optimum temperature is above that of the yeast organisms. If, however, the bacteria are present in great numbers, they may begin action at once and practically outstrip the yeast in action, therefore it is essential to use a yeast culture which is vigorous and at the same time relatively free from bacteria. There are, perhaps, certain bacteria which help out in the process of bread-making, and some authorities claim that bacteria are necessary, an assertion which cannot be accepted at present, at least not for American bread.

The essentials of a good bakery yeast are activity in fermentation, and large carbon dioxide production, and it must not impart a disagreeable taste or odor to the bread; hence great care should be employed in selecting a bread yeast. The ordinary compressed yeast of commerce

is, in general, distillery yeast which has been washed, mixed with starch or meal, and wrapped in foil to keep it moist and to prevent the invasion by moulds and bacteria. Brewing and wine-making, to be successful, are also dependent upon good yeast. In several continental European countries the fermentations are carried on in some places by use of pure cultures of species of yeast, which are found by experiment to give a satisfactory product. In this way all objectionable organisms, known as "disease organisms," are avoided. In America, however, the use of pure cultures in brewing has made but little headway, as it is claimed that by general cleanliness and care better results can be obtained than with the use of complicated apparatus such as is necessary in using the pure cultures. Moreover, under these circumstances the yeast remains fairly pure and resists action of foreign germs to a considerable extent. In England, also, pure cultures have not been found successful for ale fermentation. Among the "diseases" with which the brewer has to contend in this country are those which give cloudiness and turbidity, and brewers often claim that Americans drink with their eyes rather than their mouths — meaning that appearance counts for more than taste. The present tendency, in certain localities at least, is to get a product high in carbon dioxide, relatively low in alcohol, and bright and clear in appearance. Hence the "culture" yeast employed must be selected with care, and the disease-producing organisms eliminated so far as possible — a process involving a certain amount of technical skill.

In wine-making the process is somewhat different, and the manufacturers are still to a great extent the victims of chance, since they depend almost entirely upon the yeast which gets into the grape juice "spontaneously." The skins of the grapes are covered with cells of various kinds, among them the species of yeast which are of most use in carrying on the fermentation of the juice. Disease organisms have much readier access here than in brewing. Brewing and wine-making differ in several important respects. In brewing certain grains are employed as sources of sugary material, while wine-making deals directly with fruit juices, generally grape juice. In brewing the sugars fermented are maltose and dextrose, and perhaps levulose; in wine-making, principally fructose and dextrose. In brewing we have practically the sterilization of the liquid before the addition of the yeast, while in wine-making this is not the case. Finally, the yeast itself is different in the two cases.

In fermentation for distillation yeasts are used which act with great

vigor and give rise to large amounts of alcohol in a short time. Here it is not always necessary to be so careful as to minor details, as the main object sought is a high yield of alcohol. Certain conditions may prevail, however, which render a vigorous fermentation and large yield of alcohol impossible, unless care is taken. Should conditions favor the development of butyric acid bacteria, which are likely to be present in the mash in large numbers, trouble may result, since this acid, even in very small amounts, is extremely poisonous for yeasts; hence means must be used to prevent its formation. This is done by the introduction into the mash of a small amount of lactic acid, which is poisonous for the butyric organisms and beneficial to yeast rather than harmful. Hence if lactic acid in the proper amount be added to the mash before the yeast is added, the vegetative butyric bacteria and their spores are prevented from doing any damage and the alcoholic fermentation goes on without interruption. Practically the same result may be brought about by the action of ammonium fluoride or bismuth nitrate, salts which restrain bacterial action, but in small amounts are harmless for yeast.

Researches carried on during the past three or four years have shown that the yeast brings about the splitting of sugar to alcohol and carbon dioxide by means of an enzyme known as zymase, which exists within the cells, and from which it may be obtained by grinding with fine sand and then subjecting to pressure. The resulting substance is an opalescent yellowish liquid which will bring about the fermentation process much as yeast itself will, although less actively in some respects. Investigations as to the real nature of the press sap are now being pursued by a number of workers, for some of the most interesting questions as to enzyme action and fermentation in general are thereby awaiting solution.

One should not leave the subject of alcoholic fermentation without a brief reference to certain symbiotic relationships between yeasts and bacteria. The best known of these are the "ginger-beer plant" of England and the "kephir" of the Caucasus, used in fermenting the drink koumiss, the substance in both cases being mixtures of yeast with one or more species of bacteria growing together in the form of lumps or granules, and acting simultaneously when put in suitable media, giving rise to small amounts of alcohol and lactic acid.

Closely related to the alcoholic fermentation is the acetic, or the oxidation of alcohol to acetic acid by bacteria, as in the process of

vinegar-making. This process has been known and employed for a long time, but still it is only comparatively recently that accurate knowledge has been obtained as to the organisms involved, and even now many suppose that the process is a case of simple chemical oxidation Through the investigations of Hansen, and more recently of Lafar and Henneberg, it has been shown that there is a group or race of bacteria which will develop most rapidly in dilute alcoholic solutions, and if the temperature be favorable, will oxidize them to acetic acid and water, with sometimes the formation of an intermediate product, aldehyde.

The bacteria which bring about this transfer of oxygen from the air to the organic substances in solution present many interesting features aside from their remarkable chemical activity. Although seen to be in the form of short rods when in normal condition, soon after being put into a weak alcoholic liquid, as cider or beer, they develop rapidly into thick gelatinous surface layers, which are true zoöglœa masses. These eventually sink to the bottom of the containing vessel, forming the "mother of vinegar." With changes of temperature the bacteria undergo strange changes in shape, becoming much elongated and often swollen so that they present no similarity whatever to the original form. Such bacteria are widely distributed in nature, living especially in the earth under fruit trees and on the fruits themselves; hence, as a rule, they are constantly present in fruit juices, as in sweet cider. The different species show some variation in their action, some being of far greater value in vinegar production than others, owing to the formation of pleasant-smelling ethers of fruity odor, as well as a clear, sharp vinegar; while others produce less pleasing results, or may even oxidize the acetic acid completely to carbon dioxide and water, thus being of injury rather than benefit to the manufacturer. Here, then, is the problem for the bacteriologist: to separate the good from the useless, and to cultivate them in the pure state, if experiment shows that the best results are to be obtained in that way.

In the various lines of dairy work the bacteria play a most important part. Not only is the souring of milk brought about by microörganisms, but certain processes, known as the ripening of cream and the ripening of cheese, are due to their action. The finest butter is that made from cream in which certain bacteria have carried on fermentations, giving products of delicate flavor and aroma, and such bacteria are now to be obtained as articles of commerce under the name of

"butter culture." These butter cultures may contain a single species of organism, or may contain a flavor-producing species and a souring species, for experience has shown that if lactic acid is formed at the same time as the flavor-producing substances, the quality of the butter is improved. The chief advantages to be derived from the proper use of butter cultures are three:

1. Certainty of good product.
2. Uniformity of product.
3. Improvement in keeping quality.

The use of the butter culture is practically an application of the principle of natural selection, for the germs employed are those which have been found normally occurring in milk or cream, and which have been shown by experimental study of many species to give the finest results.

The "ripening" of cheese is a process of somewhat more complicated nature, among the many changes taking place being the transformation of casein to peptone, the formation of amido-bodies, and the disappearance of the milk sugar. Many of these changes we believe to be due to the action of bacteria or to enzymes, and the special flavor and appearance which make certain cheeses of so much value and so much sought for are the results of special methods of ripening. The bacterial changes during the process of ripening are enormous. We may have the number of bacteria increasing during the first stages from a few millions per gram to several hundred millions, and then the gradual falling off and disappearance of certain groups as the conditions become changed. Yeasts may be active in ripening some kinds of cheese, as in Swiss cheese, and moulds give the characteristic flavor to some, as in Stilton and Roquefort.

The bacteria are not all friends of the dairyman, however. Milk, cream, butter, and cheese have their "diseases," that is, defects which are brought about by various microbes. The production of red or blue milk, of soapy milk, and ropy cream, and the "puffiness" and discoloration of certain cheeses are all results of germ action, and it requires the careful investigation of the skilled bacteriologist to learn how to prevent their occurrence, and to carry on the industry with the least danger, either commercially, or from the sanitary point of view.

It should not be imagined that the bacteria which can bring about the formation of lactic acid, as in the souring of milk, are all of detriment from the commercial point of view. On the contrary, they are

often of the greatest industrial value. Two examples of their use only can here be given. Lactic acid itself is an important article of trade, as it has a wide use in industrial operations, especially in dyeing and in distilling. The acid can be manufactured far more cheaply by fermentation than by any purely chemical process — in fact, is always so produced. Some of the lactic bacteria are far more active than others, and hence a knowledge of different species or varieties enables the manufacturing chemist to produce his acid with the least waste and, consequently, the least expense. The lactic acid of commerce is made in general from corn or some grain rich in starch. This is first treated with sulphuric acid to bring about hydrolysis and then fermented, a large excess of calcium carbonate being added at the same time. By carefully controlling the temperature a very rapid change is induced through the activity of the bacteria.

The lactic fermentation finds another important application in the tanning industry, where skins of calves, sheep and goats are used for making fine leather. After the removal of the hair, the skins are put in tanks containing lime, which dissolves out certain cement substances and swells the fibers of connective tissue. The removal of the lime is necessary before the fibers will absorb tannin. Accordingly the skins are put in vats containing bran mixed with water and warmed to about the body temperature. A lively lactic fermentation ensues which causes the formation of lactate of lime, which can be washed out without difficulty.

Even the removal of the hair from skins is often accomplished by bacterial agencies. A putrefactive decay of the hair sheaths is effected, and the wool can then be easily pulled. Of the bacteria which are of use here, little is known, except that they are very active, and if allowed to act for too long a time, will produce irreparable injury to the skins. From a few personal observations I think that it is probably true also, that the liming process is in part dependent upon bacterial action, but this is an unexplored field.

The bacteria are not only of interest in dyeing operations through the lactic fermentation, but a closer application is found in the preparation of indigo. Experiment has shown that a certain bacterium is found on the leaves of the plant, and to its activity the production of the valuable coloring matter is ascribed. If the leaves are sterilized, no formation of indigo results.

Nor is bacteriology without its application to the textile industries.

In the separation of the fibers of hemp, flax, and jute, bacteria have long been employed without its being perceived that such was the case. Flax is the bast fiber of the flax plant, and in order to separate it for the manufacture of linen, it is necessary to dissolve a gummy resinous substance which binds all fibers together. This is done by a process known as *retting*. The stems are gathered in bundles and then set in tanks or rivers or ponds, where they are allowed to stay from ten to fourteen days. What actually happens is that certain bacteria present in the water multiply rapidly and bring about the decomposition of the pectin gum, thus allowing the easy separation of the fibers. The waters of certain streams are famous for their excellence in this way, as for example, the River Lys in Belgium

The food preserving industries may be mentioned as probably the most important in which a knowledge of how to combat the bacteria successfully is required. The enormous development of the canned goods industry, and the very extensive use of preserved foods of other kinds has been possible only because, wittingly or not, methods have been found for the destruction of the bacteria, or at least to prevent their action.

It is common knowledge that, unless cooked, meats and other albuminous bodies undergo putrefaction, and that starchy and sugary foods become sour. It is not because these substances are exposed to the air that they change, but because they are invaded by microbes of various kinds, and consequently are fermented. This microbial action may easily be prevented if we know the remedy and how to apply it.

The methods of food preservation which are utilized on a commercial scale are of two classes: first, antisepsis, *i.e.*, the prevention of processes of decay but not necessarily the destruction of the organisms producing it, as in cold storage, preservation with sugar, pickling, drying, and pasteurizing. The second method is sterilization, in which we stop all destructive processes by removing the cause; that is, we bring about the death of the organisms, and this finds large application in canning, *i.e.*, the enclosure in hermetically sealed packages and then subsequent sterilization by heat.

The knowledge of the behavior of the bacteria becomes a very important matter if one is engaged in any of these food industries, and lack of such knowledge has cost many business men large sums of money owing to fermentative troubles. Few people really know why sugar is a preservative in one case, and a source of trouble in another,

or why cold storage and drying are effective. The bacteriologist working with his culture tubes in all sorts of conditions explains this. He finds that cold is not as fatal to germ-life as is commonly believed, but that with low temperatures the activity of micro-organisms which produce decay is lessened, or may be suspended entirely without destroying the vitality of the germs, for if the temperature be raised again the decomposition will begin with marked energy. In a similar way the conserving action of sugar is proved to be due to osmotic changes brought about in the bacterial cells, by which the extraction of water from them results, and they are consequently rendered inert.

It is in the canning industry, however, that bacteriology is of highest importance. Here is an industry in which more than 3,000 firms are engaged in the United States, and the success of which is absolutely dependent upon the destruction of bacteria. Consider that in a single year there are packed 80–100 millions of cans of corn, and an equal number of peas, 125 millions of cans of sardines, 150 millions of cans of tomatoes, and hundreds of other foods, meats, fish, fruit and vegetables, in smaller amounts, and some idea can be gained of the importance of this industry. If all the cans of tomatoes packed in the United States during two months of 1899 were placed end to end, it would form a line more than 13,000 miles long. That is merely one of the many things preserved by canning.

As I have already hinted, lack of definite knowledge as to how sterilization should be effected, has been the source of great financial loss. This source of loss has now been largely prevented, for bacteriological investigation revealed the cause, and pointed out the remedy. It was found that in the corn there were present many spore-forming bacteria, which could withstand boiling for hours, and required heat much higher than that for their quick destruction. These bacteria attacked the sugar of the corn, fermenting it to lactic acid, and in many cases giving rise to much gas ; enough at times to burst open the cans.

Several species of these bacteria were found, some of them of great interest. Two or three species were traced to the green corn as it came from the fields, and their source thus discovered. In other kinds of spoiled canned goods, other species of bacteria were found, and in every case by study of the organisms it has been possible to provide a sure remedy against the evil.

The bacteria thus of so great commercial detriment, are of no pathogenic variety ; they are of greatest interest to the food preserver, and

in justice to the men engaged in the industry it should be said that most of the canned foods to be obtained in the markets are prepared with the greatest care, and are free from bacteria, making them of prime value as food, and without objection from a sanitary point of view.[1]

Closely connected with the food preserving industries might be mentioned the process of cane sugar refining. Here, too, the bacteria are to be reckoned with as factors of the greatest importance, since it is estimated that in some sections fully 40 per cent. of the raw sugar is inverted by bacterial enzymes and thus made uncrystallizable. If not prevented, the fermentation of the sugar may follow, giving rise to a great number of products of decomposition. Of most interest, perhaps is a change brought about by a bacterium, *Leuconostoc mesenteroides* and its allies. This organism grows but poorly when submitted to the usual treatment in the laboratory.

In solutions containing cane sugar, on the other hand, it develops with extreme rapidity, and is characterized by the formation of immense gelatinous masses of zoogloœa, sometimes of several cubic feet in size, and oftentimes completely filling the conductors and pipes of the refinery, thus entailing heavy loss. This organism is of interest, further, because of the fact that the gelatinous capsule acts as a protection to the living cell, and endows it with a certain amount of durative power so that the organism may withstand considerable periods of drying.

Recent study has shown that the number of species of bacteria which may invert or otherwise act upon raw sugar solutions is very large, and the industry is also beset with difficulties due to some extent to higher fungi, especially certain moulds.

Although less readily apparent, the rôle of the bacteria in the soil, in their relations to agriculture should be regarded as of the highest importance. Owing to the difficulties encountered in pursuing investigations in this line, our knowledge is still very imperfect, but we believe that through microbial activity the dead organic matter in the soil is transformed into mineral matter or into a form that can be utilized by green plants. Thus we get a cycle of processes taking place in the living earth. Several groups, and probably very many species of bacteria are involved in this work of breaking down matter and building it up again in new combinations. One group attacks the cellulose of dead plants, reducing it to simpler substances. Matter

[1] For a more complete account of Bacteriology in Canning Industries, see TECHNOLOGY QUARTERLY, Vol. X, No. 1, and Vol. XI, No. 1.

like urea is first hydrolized and changed into ammonium salts by another group, and the ammonium compounds are oxidized first to nitrites by the nitroso-bacteria, and still further to nitrates by the nitro-bacteria, thus completing the process of nitrification, or mineralization. The green plants then take up the nitrates, using the nitrogen in building up new protoplasmic material in the form of living cells, thus transforming the mineral matter back to organic, and completing the cycle.

Here, too, should be mentioned a group of bacteria found in the soil which enter into symbiotic relations with leguminous plants and thereby give to them the power to absorb nitrogen directly from the air. This process is known as the *fixation* of nitrogen. The bacteria enter the root hairs of the plant, increase in number, and bring about the development of nodules or tubercles. Under these conditions the bacteria become somewhat modified, some being actively motile, while others become quiescent. In a later stage the non-motile rods become branched and form a fine network known as the bacteroid tissue. When these modules are developed, the plant can take nitrogen from the air and use it in building up its own substance. This remarkable power has been found in only one or two species of plants outside the *Leguminosæ*, but practically all genera of this family can enter into this strange commensalism with bacteria, and thus these plants are characterized as nitrogen collectors, while others are nitrogen consumers. It has been suggested to utilize cultures of such organisms to enrich worn out land by inoculating the soil with them, and it is, perhaps, not too much to expect that science will turn these organisms to good account by rendering them even more productive, although the experimental stage of the process has not yet been passed.

In the foregoing pages have been imperfectly sketched some of the ways in which the bacteria have proved of use or importance in industrial operations. Others might have been mentioned. Moreover a large number of processes await investigation to prove definitely whether they are to be ascribed to bacterial causes, among them the production of silage and the curing of tobacco. Whether such changes prove to be of bacterial origin or due to enzymes produced by other organisms, there can be little doubt that the future will show many new ways in which the bacteria will be made useful to mankind.

APPLIED SCIENCE IN THE TEXTILE WORLD.

By WILLIAM W. CROSBY, S.B.

Read November 22, 1900.

WHEREVER we have accounts of the early races of man, we find that, surrounded by the forces of nature, he has endeavored to make himself the master of these forces, for he early learned that his happiness and chief good depended upon such action on his part. Where the original man depended upon the crudest of implements to till the ground by slow stages, mechanical appliances allowed him to concentrate the strength of beasts of burden upon the accomplishment of these tasks; he was enabled to provide for himself and his family some shelter other than a cave, that the fury and ravages of the stormy winds might be turned aside; he learned to make coverings for his body, adapting them to the season; but he soon found that his needs were increasing faster than his ability to supply them; for, where skins of wild beasts once sufficed for clothing, it proved cumbersome and heavy when the scorching sun shone from a cloudless sky, and the shelter that replaced the cave was not enough to protect him as it should. Just when man discovered that by interlacing small fibers material could be supplied for coverings which might be made thin or thick, and adapted to the extreme conditions under which he might find himself, is not known, but it is certain that several thousand years ago the Egyptians had developed many lines of industry in a high degree, as, for instance, spinning and weaving, making use of both form and color in their designs; for they were not content to provide alone for the comfort of the body, but also for the pleasure that might come to the eye in looking upon the design.

That most important fact which underlies the art of spinning, viz., that fibers of limited length might be made into a continuous strand by twisting them together, was a well-known principle, but for a very long time there was nothing to aid the hand in accomplishing the result. When the yarn was made and it was attempted to form the fabric, a crude loom assisted the dextrous fingers to complete the weave; true

enough, there were many beautiful fabrics, cloths of purple wrought, so it is said, with fine gold, but these were the result of the slowest kind of hand work, and of necessity were so costly as to be beyond the reach of any but the rich.

Again, we find from history that one of man's pleasures has ever been to travel abroad that he might visit with his fellow men. In the ancient days he set out with his beasts of burden, and slowly, even painfully, made his way from one place to another, with nothing to protect him from the tempest's wrath, with no means to cross streams other than fording, and arriving at his destination oftentimes so fatigued as to find little or no pleasure in the realization of his dreams. For many centuries man lived thus, although he was far from content. He mastered letters, in the fine arts he excelled, but his condition was not strikingly different from one century to another, until during the eighteenth century there came a firmer grasp upon the laws of nature, when it became evident that there must soon be an awakening, which must form the basis for an advance which hitherto had never been thought possible.

'T was well said, indeed, that "'T was ne'er entailed from sire to son; learning by study must be won;" and this is strikingly true to-day; but there is now a vastly greater field of previous successes and failures from which learning may be won. The boy in school often feels dissatisfied and chafes under the amount of work that his teacher requires of him; usually he little knows of the hours of time spent and the volume upon volume that the instructor has gone through in order that the most accurate statements may be made, that the information given may be condensed into the smallest space, and that the teaching may be as comprehensive as possible. What is attained in the present day, and that we apparently attain so much more in a given time than formerly, is due to the fact that we have learned to make these records of bygone days of more and more avail, and that we are not satisfied with learning for its own sake, but rather for what it teaches us to do in bettering our condition. When we wish to travel to-day, there awaits our pleasure a veritable palace on wheels, which defies storm and wind and rushes on over river and fen, never slackening its speed until its destination is reached. Likewise there are at our disposal an infinite variety of fabrics, machine made, and therefore at prices which all can afford, and adapted to our many wants. It is a fact that many of the attainments that have given us useful material

have not gone through any processes of inductive reasoning, but have been the result of chance: if, however, a trained mind had not been at hand to interpret, recognize, and see possibilities in the new phenomenon, in almost no case would it have developed into the reality.

The century just closed has witnessed the inception of nearly every enterprise that we now have, and that this is a fact is due chiefly to the carrying out of the principle of truth, ever and always a most lofty principle, particularly with reference to the scientific work, as mentioned before.

In this century we have had the steam engine so far perfected that we may find in a single machine the power of thousands of horses. We have the electric telegraph, which has been called one of the greatest civilizers and engines of peace the world has ever seen; more recently is given the telephone, which already enables us to talk as readily one-third of the distance across our continent as we can face to face, and there are at hand the means for indefinite extension. Our factory wheels and our street cars are moved by a waterfall, where the water has been tumbling ceaselessly and aimlessly for countless ages, waiting until the nineteenth century before it should be harnessed. Rœntgen has given the world the X-Ray, which has well-nigh revolutionized surgery, and even more, for the day has long gone by when this powerful agency has done no more than to show us the embedded bullet or the broken bone, and now opens to the physician the very inwardness of a man, showing the heart action, lung diseases and the like, as clearly as if printed upon the open page.

It is not to be wondered at that Keeley, with invisible capillary tubes, charged with highly compressed air, could impose upon a long-suffering public; nor, again, that another man could float a company which proposed to make ten electric lights burn where but a single one glowed before; nor that a Jernegan should obtain thousands of dollars belonging to other people presumably to organize a company which might extract gold from sea water, — not quite so preposterous, to be sure, as extracting sunbeams from cucumbers. There was an element of truth, however, for does not even the embryo chemist know that there are gold and silver in sea water, and does he not know that it is found in very small quantities and that some natural facility must be afforded to handle larger quantities of water at the lowest cost, if the thing is to be made practical? When Jernegan established his plant on the far-away coast of Maine he took account of all these things,

for there the tides rise high and flow swiftly. The water that might be treated at one ebb and flow would be carried far away and a fresh lot brought to hand for treatment, by nature's own forces. Here was a case where even scientific credulity was imposed upon, although by a sufficiently careful analysis it could most surely have been shown that the operation was at fault.

All this goes to show that the human family does pay deference to the productions of modern science and is ever ready to receive and appropriate new truths as they are promulgated. There must of necessity be some bad mixed with the good, some bitter with the sweet.

An historical review of scientific attainments of bygone days shows that many phenomena were observed and many individual investigations made, but each was distinct by itself and had little or no connection with others. They added little, if anything, to the happiness or advancement of the human family, so that when they did become, in later days, of some importance, and when there appeared a particular connection between themselves and the daily affairs of men, they were discredited. In other words, there came to be drawn a very strong line dividing theory and practice.

At the present time this barrier is fast sinking. In nearly every case where we hear it said that theory and practice do not agree, we can find by investigation where the theory was wrong or incomplete, usually the latter, or where the practice was imperfect.

There never was a time in the world's history when advancement along all lines of manufacture has greater impetus than now. We have striking illustrations of the relations between manufacturing countries where trained skill is employed and those where it is lacking. It is shown that, within the United States, those States that do most for education have the highest productive capacity. With an average duration of school attendance in a recent year of 4.4 years for the United States at large, Massachusetts showed seven years and Tennessee but three years. The productive capacity of the United States at the same period was 55 cents per day, Massachusetts 85 cents, and Tennessee 38 cents. The expenditures were, for the United States, $2.67 *per capita* of population ; in Massachusetts, $5.07, and in Tennessee, 83 cents. This is not an isolated case, although it is a very strong one, and its lesson is obvious.

We have seen in our own country a most phenomenal growth in

the iron and steel trade. Why have we been able to build bridges in a shorter time and at a less cost, to be erected in a far-away continent, where all the mechanical appliances to be used in their erection might be had only by taking them there, where men used to our climate have worked under tropical suns and under the most adverse conditions, and then have received the well-merited applause of the whole world? Why have we been enabled to build locomotives, adapting them to the particular conditions of countries all over the earth, and to place our products in competition with the world? Why have we made tons upon tons of water wipe to send to Australia? Why are there many representatives from the far-away "Yankee land of the East" in our country to buy looms? Again let me ask, why have we been able to do these things within the last decade and not before? Surely not because the iron ore was not in the mountains, nor for the lack of coal, nor yet for the lack of capital. There can be but one answer. Because we did not know how.

From time immemorial the man who has mastered letters has been universally looked up to as the possessor of something occult, that he was far above those who had not his attainments. Those professions that depended upon such a knowledge were accordingly placed on a high pedestal long ago, while he who shod your horse and mended the tire on your wagon was looked upon as one possessing a trade, which was to be attained only by the repetition of those selfsame operations. To be sure, the man of letters could have learned those operations, and doubtless they would have been learned very well; but the step from the blacksmith's anvil to the great hammers weighing many tons, which now forge the frames for a multitude of new machines, the field rings which make possible the gigantic generators at Niagara, the armor plates which protect our battleships, and the shafts which drive these ships from ocean to ocean, would never have been possible if something other than manual dexterity had not been acquired.

It was not often that the apprentice ever exceeded his master in skill, and if he did it was in some trifling detail, if he depended upon his hands alone. When once it was realized that the advancement in any line was attained, not by a great manual dexterity, but by an application of the mind through the hand, then we had the inception of scientific schools.

Without doubt the high position of our own country in the affairs of the world along the lines just spoken of may be ascribed to the

training that we have had through these scientific schools. There is one school which dates back to about the first quarter of the last century, but those that are now the largest and best known date back to within only the last half century — far enough back, however, so that the graduates may take important positions in the manufacturing and mercantile enterprises which are so far in the lead of our great prosperity.

The growth that is of the most importance is the one whose roots have sunk deep enough to supply in the dryest time the trunk and branches with the needed nourishment, where the minimum flow must never be less than such an amount as will satisfy the demands of the whole. Such a growth is of necessity slow, and usually the slower the growth, the firmer will be the substance, well fitted to withstand the storms and ravages of time.

The centuries have been accumulating a fund of knowledge, which is now in our hands; it has led us to the position where we can advance much more rapidly than of yore, each success making way for many new and useful things. Suppose the carpenter to be building for you a house; nowadays he selects for his stock the frames, boards planed and finished, mouldings, floorings, doors and window frames, where once he was fortunate to obtain the lumber roughly squared and dry enough to work. What is the result? Does the carpenter know less, or are these various specialists mere machines of parts of their machines? Does it throw out of employment the high-priced man who could perform all these operations? No; rather it opens up countless other positions in allied industries, giving in almost every case employment to a far greater number of men, and with the added advantage that the product may be within the reach of a vastly larger number of people, whose homes may be beautified, or made comfortable, or both. Who a hundred years ago ever heard of a motorman? Or what would our forefathers understand by such terms as conductor, lineman, stoker, brakeman, bacteriologist, analyst, or, indeed, a score of others?

Each specialization brings a new field with its many positions into view, and adds rather than cuts down the number of available opportunities where men may work. To be sure, many improved machines do away with an amount of manual labor, but require more and better skilled labor at the head of the line. The law of the survival of the fittest must ever dominate.

In seeking to surpass previous attainments, man long ago had provided well for the necessities of life, and not much was lacking to make

him comfortable, but he was not satisfied with this; he launched out in all directions; he would have fruits from the tropics, spices from the East, tea, coffee, and, in fine, everything to be had in the world, and would exchange for them his own products. He must have ready and efficient means for communication, that he might travel and visit wherever he chose. He was not satisfied to clothe himself with that which would make his body merely comfortable; he sought to adorn it, and the coverings of the walls and floors of his house have been treated similarly.

There is no more striking mark of the advance of civilization of a people than the degree of beauty in their structures, — this term being used in the broadest sense, comprising whatever must be put together for some particular use, but is nevertheless susceptible to adornment, — and this is especially apparent in the textile fabrics.

There is no department among the industries of the world where there has been a greater lack of well-trained minds than in producing the countless varieties of fabrics with which we clothe ourselves and beautify our homes. To be sure, it is not so very long a time since there was nothing but the crudest form of hand machine to clean the fiber, make the yarn, or weave the cloth; and until the cloth itself could be constructed there was obviously no chance to even attempt to beautify.

The tapestries of the olden time and the fabrics with their intricate designs were made by the slowest process of hand work, and were therefore so costly as to be beyond the reach of the masses. When power machinery was introduced, the quantity of the output was increased, a uniformity of product secured, and a great reduction in price made, although none but the plainest of goods was produced. This was the first great step forward, but in a work on cotton manufacture, published no longer ago than 1836, it is stated that "the plain loom is running well, and great hopes are entertained that there will soon be a power loom for weaving fancy goods." There have been great difficulties for the manufacturer to overcome, and there has been, accordingly, the greatest tendency for him to continue with a given line of goods, so long as a market could be found, changing only when necessary to keep up the trade.

The apprentice system was good, and it turned out men who managed these enterprises in a masterly way, but who shall say that it might not have been better? It is not in the power of every one to

impart knowledge, and the young man who depends entirely upon his own quickness of perception, and what he may acquire by chance from others, is most surely handicapped in the race with the elements, as compared with him whose mind is directed by those selected for their capability and skill in whatever line it may be. There is not a lack of properly developed artistic ability to blend form and color in perfect harmony ; this has been in the world for centuries. It is the *mechanical means* to reproduce these things that has been lacking. Who can estimate the uplifting influence of the numerous photographic, lithographic, and other printing processes in scattering broadcast, and bringing within the reach of the poorest, the best art in the world? While this may have its effect upon civilization, people are not compelled to look at such things, as they are compelled to look upon their clothes, carpets, and hangings, which contribute primarily to their comfort, and yet have been well-nigh hideous to the sight. Here we meet the serious question of mechanical devices to further our ends.

Wonderful results have been obtained, but the field is wide for conquest. Even now many processes are crude, but the means for study and investigation are increasing fast.

Foreign countries are far ahead of us. Germany in particular has a most elaborate system of schools in direct touch with nearly every department of industry, and is, accordingly, occupying an enviable position with relation to the world's affairs, though according to our standards their schools are chiefly trade schools.

A piece of plain fabric, long a standard product of our mills, is worth, as raw stock, some eight or nine cents per pound, and only eighteen cents per pound as print cloth ; to this additional nine or ten cents are charged the pay roll, repairs, taxes, insurance, depreciation, waste, and a very small profit. A bit of Swiss muslin is worth but little more in the raw stock, yet with the same pound of cotton in twenty yards of fabric will sell for $8 or $10. Is it not time that we were alive to the situation?

In developing the higher grade of goods, particularly with color added, we must take advantage of almost all the research of modern science ; at least, we must appropriate something from every department, for the degree of precision attained demands an application of skill in a continuously increasing quantity.

The question of trade schools and of how far science may be applied to art without losing its identity has been long a subject of discussion.

It needs no extended argument to prove the value of the application of the principles of pure science to the production of tangible results.

The gap between pure science, particularly in mathematics and physics, on the one hand, and applied science on the other, has been in many cases as great as between science in general and the so-called practical part of the world; and it is even amusing to a disinterested spectator to note the apparent astonishment on the part of certain speculative mathematicians, whose great delight is in the 4th, 5th or *nth* dimensions of space, when they are shown tangible results that can be laid off and measured with a foot rule, emanating from many-fold integrals.

If we admit that material progress is dependent upon a perfectly secure footing in the principles of science, we must not leave any stone unturned until these fundamentals shall be as surely established as is the rock of Gibraltar. One man or set of men must enunciate and substantiate the purely theoretical part of the work, and another must take up so much of that as may be necessary to the completion of their ends, for it is obvious that no one man can live long enough to dominate both fields. While not discrediting the trade school, so called in the strictest sense of the word, one should look with some suspicion upon it, if it does not make use of the latest and best methods of science, — not depending upon the result alone, but inquiring carefully into the correctness and reliability of all the elements. It is not enough in many cases to give a man a general training which will enable him to understand the deductions of the purely theoretical side, leaving him to find an application for himself. True, there will always be a demand for a large number of these men, but there will be an equally great, if not greater, demand and for a larger number of men who are one step further removed from the purely theoretical side, and at the same time are more strictly in touch with the material or result-yielding portion of the community.

There is invested in the State of Massachusetts in the textile industry about one hundred and sixty-seven million dollars. While there is a question in the minds of some as to whether the cotton industry will survive the competition of the South, there surely is not any need to fear a very immediate removal. There are certain features of the case which will eventually change, so that the question of labor, taxes, insurance, and others closely allied, will doubtless soon settle themselves. With all this capital invested, it can safely be taken for granted that if we cannot make the coarser grade of goods, we will make the finer. It

is, then, no wonder that hitherto the large proportion of our cotton crop should be sent abroad, manufactured into the finest goods, sent back here and sold over the counters of our stores; for we have not been providing the means to properly train our own people, who should have been employed in manufacturing these goods, while across the water every possible means has been brought forth. Long ago we found ourselves solving well some kindred questions. More recently we have taken up the problem of the application of science to the textile world, and we find that the further we travel, the higher we climb, just so fast does the horizon, which seems to mark the limit of attainments, recede.

The leading manufacturers of Lowell long ago realized the necessity for meeting this problem, and after much study organized as the Trustees of the Lowell Textile School. In this school they have collected such machines as are in use in the production of the fabrics of the present day, and have assembled a corps of instructors who are entirely familiar with the practical running of these machines, and at the same time, so far as possible, are thoroughly well grounded in the theoretical side of their several branches. It was seen early that such a school must, first of all, produce as good results as were attained in the best mills, and when this point was attained, all the research of modern science must be brought to bear if any advance was to be made. The work soon developed into the laboratory method, the instructor first covering the ground by a lecture, and afterward causing the student to produce the tangible result upon the machine. When it is realized that at the present time almost endless numbers of effects in the finished goods are produced by combinations of fibers, chemical changes, etc., it is not hard to see how extensive an equipment is necessary to handle such work.

The school already has complete equipments for producing the different varieties of cotton, woolen, worsted and other yarns, making the designs, ornamentations, and harmonizing the colors for the fabrics, weaving the same, as well as handling the chemistry and dyeing which may be necessarily connected therewith. The school has been in operation a sufficiently long time to observe the results attained to some extent, and it is found that these results have been good; for everywhere the manufacturer is realizing, as never before, that he must have trained skill in and about his mill; and on the other hand, it is seen that science alone is of small avail if it be not applied.

BOOK REVIEW.

Electrical Testing.[1]

As a result of the rapid development of the profession of Electrical Engineering and the consequent necessity of giving an adequate experimental treatment of the various branches of the subject, the demands on the time of the student have become most exacting. This forces one to consider most carefully the general arrangement of laboratory work and the particular experiments which should form the course. As it appears to us, the subject of Electrical Testing should be one that not only furnishes the student with certain tools of trade, but should possess a real educational value in establishing a critical attitude of mind in respect to all experimental work. Therefore only the best methods should be included in the course, and these should be accompanied by a suggestive text in which possible sources of error are adequately discussed. It is with these things in mind that we turn to the recent volume by Professor Parr.

The sub-title, "A Course Suitable for First and Second Year Students and Others," explains in a measure the nature of the experiments included in the book, and the statement that the volume is to be followed by another which will treat of experimental work of a character more intimately connected with electrical engineering, may be taken as an explanation why certain things are omitted.

The book is divided into four parts. The first is a laboratory manual of 215 pages devoted to direct current measurements, including properties of iron and measurement of inductance. In this section the subject matter is divided into 120 sections, nearly every one of which treats of a distinct experimental method. Following this is an appendix of 30 pages in which demonstrations of the various formulæ occurring in the first part are to be found. A section of 101 pages treats of apparatus, and is illustrated by cuts of instruments by

[1] Practical Electrical Testing in Physics and Electrical Engineering. By G. D. Aspinall Parr. New York: Longmans, Green & Co. 392 p., 231 ill. $2.50.

well known makers, as well as those in the laboratory of the author. The concluding pages are occupied by Tables of Constants, Logarithms, Trigonometrical Functions, Squares, Reciprocals, Doubled Square Roots, and an Index.

Each experimental section is subdivided as follows: An introduction containing in a condensed form the theoretical consideration on which the experiment is based. A statement of the apparatus required. Instructions as to carrying out the observation, and in some cases specific questions on the preceding work.

On opening the book one finds that the first section is on Curve Plotting, but the capabilities of the Graphical Method for determining the constants in particular forms of equations are not referred to. Another noticeable omission is that of all precision discussions, as well as those pertaining to best arrangements of apparatus. Also no adequate treatment of possible sources of error in the various experiments is given.

The elementary nature of the earlier experiments is probably explained by the fact that the book is for the use of first year students; but it seems to us that a number of them might with profit be omitted, especially if the student has had previous training in manipulation. For instance, there are four methods of measuring galvanometer resistance; eight methods for battery resistance; and nine methods of comparing E. M. F's. We understand that the book is not a compendium of methods, but a laboratory manual, and as such the methods presented to the students should be those of approved value.

The instructions for the experimental work are so specific that much of the educational value of the laboratory training is lost. A notable omission is that of all calibration work, one of the most important branches of Electrical Testing.

In view of the foregoing, our chief criticism of this laboratory manual is that it fails to embody those results of criticism and of personal experience which contribute so much to the training of the student and qualify him to attack new problems in the most advantageous manner.

FRANK A. LAWS.